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ANATOMICAL CHARACTERS OF THE SEEDS OF LEGUMINOSAE, CHIEFLY GENERA OF GRAY'S MANUAL.

LOUIS HERMANN PAMMEL,

B. Ag., University of Wisconsin, '85; M. S., University of Wisconsin, '89;

Candidate for the Degree of Doctor of Philosophy in Botany.

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CONTENTS.

ANATOMICAL CHARACTERS OF THE SEEDS OF LEGUMINOSAE, CHIEFLY GENERA OF GRAY'S MANUAL.*

L. H. PAMMEL.

At the suggestion of Professor Trelease, the writer (*195*)† made a study of the seeds of several leguminous plants in 1885. The genera *Gymnocladus*, *Mucuna*, *Phaseolus*, and *Physostigma* revealed so many interesting points that a comparative study of the genera, chiefly of Gray's Manual, was begun in 1886 and 1887 but, owing to other work, it was dropped and not till the year 1896 did I have an opportunity to take the subject up again. Since 1885 many papers bearing on the subject of seeds have appeared.

It gives me great pleasure to acknowledge the assistance received from Professor Trelease, who has given me every facility of the Missouri Botanical Garden. Such literature as was needed was cheerfully obtained for me. I desire also to thank Miss Charlotte M. King for the reproduction of my drawings, and Mr. C. R. Ball, for several favors shown me.

HISTORICAL.

The first account of leguminous seeds we owe to Marcellus Malpighi (161, 87. *f. 301–302*), 1687, who states that what are now known as Malpighian cells (ducts) are partitioned. Gärtner (67, 2: 301–352. *pl. 144–156*), 1791, in his classic work, described chiefly the external characters of seeds, but in some cases the structure of the testa, endosperm, and embryo are given. Rudolph Boehmer (21), 1785, in a general way also treats of seeds. Bischoff (17), 1833, briefly describes the testa of *Vicia Faba* and *Cicer arietinum*.

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† The number in parenthesis refers to bibliography at the end of paper.

A general account also appears in his Lehrbuch der Botanik (18). Schleiden and Vogel (234), 1839, 1842, studied the seeds of several representative *Leguminosae*. Pringsheim (202), 1848, in his inaugural dissertation, describes the testa in *Pisum sativum* and *Vicia Faba*, giving some excellent illustrations; Adolfo Targioni-Tozzetti (257), 1855, of *Vicia polyantha*. Russow (212. 213), 1871 and 1872, in connection with his work on the comparative anatomy of *Marsiliaceae*, refers to the structure and nature of the Malpighian cell, especially the light line. Sorauer (250), 1872, Le Monnier (148), 1872, and Wiesner (285), 1873, incidentally refer to the structure of some leguminous seeds.

Strandmark (254), 1874, studied the seeds of the orders *Cucurbitaceae*, *Solanaceae*, *Resedaceae*, *Capparidaceae*, *Geraniaceae*, *Convolvulaceae*, *Hydrophyllaceae*, *Violaceae*, *Caryophyllaceae*, *Malvaceae*, *Cruciferae*, and eleven genera of *Leguminosae*. Nobbe (190), 1876, gives some details of a few economic species. In 1874, Sempolowski (247) gave a complete and accurate description of the genera *Lupinus*, *Vicia*, *Ervum*, *Pisum*, *Trifolium*, *Medicago*, *Melilotus*, *Ornithopus*, *Anthyllis*, *Trigonella*, and *Onobrychis*. Chalon (39), 1875, published an extended paper, the first part of which is devoted to the structure of the testa, and the second to the endosperm.

To Haberlandt (83), 1877, we owe an account of the development and structure of the seeds of the genus *Phaseolus*. Günther Beck (8), 1878, described the testa, endosperm, and embryo of the economic genera *Vicia* and *Ervum*. The previous autumn, Junowicz (128), 1877, gave detailed accounts of the Malpighian cells in several *Leguminosae*. Godfrin (71), 1880, in his paper on the testa of angiosperms, described *Lupinus*, *Vicia*, *Orobus*, and *Trigonella*. Harz (99), 1885, in his extensive study of the seeds of economic plants, gives accurate and detailed accounts of many leguminous seeds. Tichomiroff (260), 1884, briefly notes the microscopic characters of the seed of *Abrus precatorius*. Mention should also be made of the work of Hanausek (91), 1884, and Moeller (179), 1886, and other pharmacognostical writers who have discussed the seeds of medicinal plants. Mattirolo (169), 1885, made a study of the light line of the seeds of several orders, including the *Leguminosae*, in order to settle some of the conflicting theories concerning this peculiar band. The following species were studied by him: *Lupinus albus*, L., *Phaseolus* sp., *Vicia Faba*, L., *Trigonella Foenum-graecum*, L., *Ervum Ervilla*, L., *Pisum* sp., and *Acacia prismatica*, Hffsg.

Among the later writers who have taken up the seeds of the order, mention should be made of Nadelmann (185), 1890, who describes the anatomy, development, and the transformation of the reserve cellulose in the endosperm and embryo of leguminous seeds during germination. Tschirch (265), 1889, in various parts of his work, discusses the chemistry, structure, and function of the testa, embryo, and endosperm. Mattirolo and Buscalioni (174), 1892, in a splendid monograph, have given us one of the best recent accounts of the structure of different parts of the seed, as well as the functions of different parts of the testa. The paper is accompanied by an excellent bibliography on seeds. Some excellent figures and descriptions are contained in the "Anatomischer Atlas" of Tschirch and Oesterle (267). Two recent papers have come to my notice, one by Pfaefflin (199), 1897, who worked under the direction of Tschirch, and the other by Marlière (164), 1897.

GENERAL HISTOLOGICAL DISCUSSION.

Macrosclerids. Malpighian Cells.

Malpighi (161) undoubtedly observed these cells, as his figures and descriptions show, and this led Targioni-Tozzetti (257) to apply the name Malpighian to them. Schleiden and Vogel (234), 1838, in their classic paper, apply the term epidermal; Sempolowski, 1874, calls them palisade or epidermal; Strandmark, 1874, epidermis; Chalon, 1875, carapace; Haberlandt, 1877, and Junowicz, 1877, prism cells, Prismenschichte; Russow, 1871, 1872, and Beck, 1878, Hartschichte; Beck, 1878, Hanausek, 1884, Harz, 1885, Moeller, 1886, Nadelmann, 1890, Kayser, (386), 1893, palisade cells.

The term sclerid was proposed by Tschirch (451) for those mechanical elements which are much shorter than bast cells, as a rule not fusiform but blunt, with walls often greatly thickened, stratified and lignified, with oval or rounded pits. In the strongly thickened forms, pore-canals occur. In a later work (265) he adopts the same classification and expands somewhat on the Malpighian cells.* In the joint work of Tschirch and Oesterle the same term is applied. Haberlandt (85) uses the same term in a general way but calls the Malpighian cells of leguminous seeds "palisade sclerenchyma" and refers these to the same category as those found in the seeds of *Cannabis*.

It is obvious from what has been said that the term palisade should not be used, as it is usually applied to the elongated, thin-walled parenchyma of the leaf, where it has an important function to perform in connection with photosynthesis, while the function of the Malpighian cells is chiefly mechanical. I have, therefore, adopted Tschirch's general classification and for this special case the term "Malpighian." Concisely stated, these cells are longer than broad, with blunt or rounded ends and one or more clear, lucid lines extending across the narrow diameter, the so-called light lines. In the order *Leguminosae* these cells are nearly universal. They vary in size just as the seed does. They are strongly developed in *Gymnocladus* and *Gleditschia*, less so in *Trifolium*, some species of *Phaseolus* and *Medicago*, nearly wanting in *Stylosanthes* and *Arachis*, and absent from *Chapmannia*. Under "light line" I have discussed these cells in various orders besides the *Leguminosae*.

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* Tschirch's classification is as follows: —

A. Sclerids.

1 Brachysclerids. Nearly isodiametric, strongly thickened. Cortex, *Quercus* and pimenta.

2 Macrosclerids. Elongated with blunt ends.
Palisade cells of leguminous seeds: — *Trigonella, Physostigma.*
Testa of *Ricinus, Croton,* and spicular cells in the seeds of species of *Welwitschia.* The sclerenchyma fibers of cocoanut fruit. The brittle inner layer of the nutmeg.

3 Osteosclerids. Enlarged at both ends like the human femur. In leaf of tea. Support cells (I-shaped cells, T-shaped cells) occurring in the inner layers of many seeds, as *Abrus* and *Trigonella.*

4 Astrosclerids. Many branched sclerids, the branches mostly with a conical point. In leaves of *Camellia, Dammara,* and bark of pine.

CUTICLE. — The cuticle makes its appearance quite early in the development of the ovule. In the mature seed it is represented by a delicate line, as a rule of nearly equal thickness. On the addition of chlor-iodide of zinc or iodine and sulphuric acid, it is colored yellowish-brown. It is dissolved in Schulze's mixture.

The cuticle has the well-known property of not allowing water to pass through, or only with difficulty. The waxy or fatty nature of the cuticle is repellent to water.* Its thickness is correspondingly increased in the seeds of *Mucuna*, *Gymnocladus*, and *Gleditschia*, where germination proceeds rather slowly. The remainder of the cell-wall in leguminous seeds is not homogeneous but there is a more or less differentiated part which I have designated as the cuticularized portion, though not necessarily chemically the same substance. Mattirolo and Buscalioni (170. 174) designate the cuticle as "strato esterno della membrana di rivestimento" or outer covering membrane, and the cuticularized layer as the "strato interno della membrana di rivestimento" because the structures do not correspond to those of epidermal coverings.

Schips (226), who has investigated the question, concludes that the outer layer is the cuticle, and that the layers below are frequently differentiated into two additional parts one of which is more or less mucilaginous.

The substance of the conical projections colors blue with sulphuric acid and iodine and rapidly dissolves; a less soluble part also colors blue with sulphuric acid and iodine. Schips compares these with the intracellular mucilaginous thickenings in the cell-walls of some orchids, as described by Noack (414) and Magnin (399). The cuticularized layer is conspicuous in many seeds of the order, especially in *Gymnocladus*, *Gleditschia*, *Cassia*, and *Parkinsonia*. True, it does not always reach the development found in the epidermal leaf-cells of *Agave* and *Aloe*, well-known representatives of dry climates, yet the cuticularized layer is well marked. From the interior of this layer occur tooth-like projections that

* Frémy (337) applies the term cutose to the insoluble material of the cuticle, which is derived from fatty and waxy deposits in the cellulose membrane.

separate pore-canals. The pore-canals extend into the cellulose portion of the cell-wall. The remainder of the cell-wall colors blue, except the light line, when treated with chlor-iodide of zinc or sulphuric acid and iodine. Such are the reactions in *Cassia*, *Gleditschia*, *Aeschynomene*, *Mucuna*, *Lespedeza*, and many others studied. The cell-walls of the osteosclerids and the sclerotic parenchyma in the nutrient layer of the mature seed of *Baptisia* and of *Cassia marylandica* color blue more rapidly than the walls of Malpighian cells. The cellulose of the cell-wall is slowly acted on by cupric ammonia, zinc chloride, and hydrochloric acid. Sulphuric acid also causes a dissolution of the membranes. In some few casés phloroglucin and hydrochloric acid show that lignin is deposited at the base of the cell as well as in the cuticularized layer, as in *Baptisia leucophaea* and *B. australis*. The reactions are shown more clearly in Tables A and B.

Pore-Canals and Cell-Cavity. — The Malpighian cells are not uniform as to thickness; the cell-cavity is as a rule larger in the lower than in the upper end, but it may widen somewhat near the light line in the upper part of the cell, as in *Gymnocladus* and *Gleditschia*. In a surface section the Malpighian cells are five or six-sided with a large central cavity and radiating, frequently branched canals. Serial cross sections show that the central cavity increases in size inward, at the same time the radiating canals disappear. These canals are certainly not to be compared with the folds occuring in the petals of many flowers, as in *Petunia* and *Pelargonium* (372), or in the leaves of *Pinus* (318), *Aspidium aculeatum*, and other plants (395).

In *Strophostyles pauciflorus* the cell-cavity is large in a seed that is about half grown. The lateral walls show some thickening, more above than below, and the outer wall receives deposits of cellulose at certain points, and as the seed develops, more is added to these points. In a mature seed these meet the cell-wall and usually a complete separation from the original cell-cavity occurs. Some writers speak of "Leistenförmige Verdickungen," a term not entirely inappropriate. The true nature of these canals may be seen in sections treated with Schulze's medium, after thoroughly washing and then staining with methylene blue. The canals are simply remnants of the original cell-cavity containing some plastic material. Their true nature and structure are well shown by Marlière (164. *pl. 1. f. 5c.*).

CELL CONTENTS. — In the unripe seed, asparagin commonly occurs. The nucleus is made out readily, especially when stained with haematoxylin. Chromatophores are more common in the unripe seed but frequently persist in the ripe seed, as in *Trifolium*, *Vicia*, and *Phaseolus*. Other proteid products also occur. So long as the seed is soft, coloring matter is not deposited, but when the drying process begins coloring matter is deposited, in spots, as in *Mucuna*, *Phaseolus*, *Wistaria*, or uniformly in the walls, as in *Vicia*, *Trifolium*, *Medicago*, and *Phaseolus*. The coloring matter varies in different genera and species. The general name anthocyanine has been given to it. Some of the pigments have received special names, as lathyrin, cytisin, and numerous others.

Tannin is always found in greater or less quantity; this is most rapidly deposited during the ripening period of the seed. Likiernik (149) notes the occurrence of lecithin, which was first found by Schulze and Steiger (243) in the testa of some leguminous seeds, and probably occurs in the Malpighian cells. Likiernik obtained a second special product which he has called lupeol, a substance resembling cholesterine; from the pea, phytosterin was obtained; from the common bean, two products were obtained, paraphytosterin and phaseol.

LIGHT LINE. — The light line, "linea lucida," "ligne lumière," "Lichtlinie," of various writers, is the most interesting feature of the Malpighian cell. As a rule but a single line occurs in *Leguminosae*, but in *Gleditschia* and *Cassia* there are two. In *Lespedeza*, *Phaseolus*, and *Pisum*, but one. Junowicz (128) gives three for *Lupinus varius;* Sempolowski (247), two for *L. angustifolius;* and Lohde (396); two for *Quamoclit luteola*. None occurs in *Chapmannia*.

Numerous theories have been advanced as to the chemical nature, physical properties, and function of the light line. These views are by no means harmonious, in part because writers have worked with different plants. The position of the light line varies in different plants. It may occur in the testa, the wall of the ovary, or the wall of a sporangium. In all cases, so far as I am aware, it is connected with a reproductive body, and obviously has some function. It may be of interest to briefly review the theories concerning it.

Mettenius (407) states that perhaps it originates from the pore-canals all appearing at the same height in these cells, but he was unable to make these out in cross sections. Schleiden and Vogel (234. 235, 76), in describing the mature testa of *Lupinus perennis*, *L. rivularis*, and *Acacia Farnesiana*, thought the walls of the upper and lower parts of the cells were unequally thickened, the cavity entirely disappearing in the upper part of the cell. Targioni-Tozzetti (257.–99, **2**: 561) suggested that the light line in *Vicia polyantha* was due to numerous thickened, refractive points found above the middle; below this a wide cavity with a thin wall. Hanstein (363.–99, **2**: 561) gives an explanation of the light line in two places. At first he considered that the Malpighian layer consisted of a double row of cells. Later he attributed the phenomenon to a perforated disc at this point, which transmitted the light.

The earlier accounts of the light line were based on observation. Russow, however, studied the light line under polarized light and tested it with microchemical reagents. He concluded that it had a modified molecular structure, containing less water than the remainder of the cell-wall. In *Marsilia* the light line is anisotropic.* Lohde (396) agrees with Russow in regard to the anisotropic nature of the light line. In *Convolvulus* and *Quamoclit* the Malpighian cell, except the light line, colors blue with sulphuric acid and iodine, the parts being less soluble in the region of the light line than elsewhere. In *Hibiscus Trionum* the light line is cuticularized.

Sempolowski (247), who investigated the light line in *Lupinus* and other *Leguminosae*, states that there is not only a difference in the molecular structure but also a chemical

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* On this general subject see Zimmermann, Beiträge zur Erklärung d. Anisotropie d. organisirten Substanzen, — in Habilitationschrift, Ueber Zweck u. Mechanik d. hygroskopischen Gebilde der Pflanzen. Berlin.

modification of the cell-wall at this point, since with iodine and sulphuric acid the cell-wall colors blue, whereas the light line colors yellow. Haberlandt (83), who studied the development of *Phaseolus vulgaris*, accepts the Russow explanation, that the light line is clearer and contains less water than the other parts of the cell, while it colors blue with chlor-iodide of zinc.

Beck (8) thought the appearance might be due to a chemical alteration, but micro-chemical tests did not reveal its nature, though it has but a slight affinity for water. The light line is more refractive than the rest of the wall and chemical changes have taken place. It has certainly not been demonstrated that there is a difference in the amount of water. It is not cuticularized. When stained with carmine and aniline dyes this portion of the wall does not take the stain as readily as others.

Junowicz (128) found undoubted evidence of cellulose material. The cell-wall at this point was strongly refractive and had a different molecular structure. It was never chemically changed, *i. e.*, cuticularized. Fickel (332) who studied *Cucumis sativa*, speaks of a lignification at this point. Harz (99, **2**: 562) accepted the Russow explanation and adds that it is due entirely to physical changes in the laying down of cell-wall substances; it contains less water. It is significant that in several cases mentioned by him the light line disappeared on the application of nitric acid. Tietz (261) considers it due to a chemical modification. Chalon (39) does not express an opinion. Brandza (26) does not seem to have investigated the subject very thoroughly, but gives it as his opinion that a chemical modification has taken place. Wigand and Dennert (471) suggest that it is due to a series of erect fissures, and that the Russow explanation is not correct. Weberbauer (467), who studied the same species of *Nelumbium*, agrees with Wigand and Dennert.

Wettstein (468) agrees with Russow and Sempolowski that chemical and physical modifications occur. The light line slowly colors blue. The absence of pore-canals in the region of the light line causes it to be more dense, as shown by microchemical tests, and its contact with the neighboring porous part of the cell-wall intensifies the luster of the light line. Mattirolo (401), after some careful studies of the light line in *Tilia*, concludes that in this genus it consists of true lignin; in some other plants it approaches it. In *Leguminosae* no lignification occurs as a rule. Overhage (415), who studied the seeds of *Canna*, agrees with Mattirolo that this portion of the Malpighian cell is lignified but thinks that this does not account for all of its peculiarities, and in part these must be due to a peculiar molecular structure. It is doubtful whether Overhage studied the light lines carefully. Humphrey (382) does not commit himself, but says: "Overhage states that the walls in the region of this line are lignified, as Mattirolo has shown to be true of many other seeds."

Huss (118) states that the appearance of the light line must be explained by its physical properties rather than differences due to chemical composition. Marlière (164, 5) gives a physical explanation. "The true cause of the light line lies in the structure of the secondary membrane of the Malpighian cell. When viewed tangentially the cells have an irregular, strongly reduced cavity which projects into the secondary membrane at the points where the narrow lumen occurs. These points penetrate almost to the primary membrane. They are cut out even to the secondary wall. The canals of the cells are strongly acute, generally half cylindrical, leaning towards the primary membrane. The strong thickening of the membrane which surrounds the cell-cavity forms a homogeneous medium for the transmission of light; it thus becomes strongly refringent, more so than any other part of the wall. The depth of the wall through which the rays of light have to pass multiplies their reflections at the expense of their intensity." This, to him, seems to be a probable explanation. Kayser (386, 88) considers that both chemical and physical modifications have taken place in *Convolvulaceae*.

LIGHT LINE IN OTHER ORDERS. — From the above general review of the subject it will be seen that the views are by no means harmonious. It would be presumptuous on my part to conclude, because the reactions in *Leguminosae* are not the same as Mattirolo has described for *Tilia* or Kayser for *Ipomoea*, that these and other writers have been mistaken in their conclusions. I have therefore compared the Malpighian cells of the orders *Tiliaceae*, *Sterculiaceae*, *Malvaceae*, *Cucurbitaceae*, *Labiatae*, *Convolvulaceae*, *Rhamnaceae*, *Geraniaceae*, *Nymphaeaceae*, *Scitamineae*, and *Marsiliaceae* with those of *Leguminosae*. So far as possible I have taken representatives of the orders heretofore studied.

Tiliaceae. (Mattirolo 401, 10. Brandza 26, 115–116. *pl. 8. f. 6–7*). In a nearly mature seed of *Tilia heterophylla* two rather wide light lines occur, one a little above the expanded part of the cell-cavity, the other beginning near the end of the Malpighian cell. When treated with chlor-iodide of zinc, the upper part slowly colors a bluish-black, as in *Sterculia*. The cell-wall below rapidly responds to the action of phloroglucin, coloring wine-red and the light line fainter, indicating lignin. Mattirolo shows a very striking wine-red color in *Tilia argentea* as well as in the lower part of the cell, though I find the reactions not so strongly marked in the light line, which may perhaps be attributed to the seed being somewhat unripe. The ripe seed of *Tilia Americana*, agrees however with *T. heterophylla*. The chlor-iodide of zinc test is just as positive. The whole broad zone in the upper part of the cell-wall colors bluish-black, which would seem to indicate that it consists partly of cellulose, and that lignification has not proceeded so far.

Ripe seed of *Tilia Americana* shows a very distinct lignin reaction in the lower part of the Malpighian cell. The narrow line just under the cuticle gives the reaction for lignin, but the color is not so bright. Iodine alone colors the Malpighian cells pale yellow. All parts are nearly alike at first, but longer action causes the lower part to become darker in color. When very dilute sulphuric acid is added the narrow light line is conspicuously pale straw color. With stronger acid the cell-wall is rapidly dissolved. Disintegration begins in the region of the upper light line. The middle lamella becomes black and resists its action longest. The walls of the Malpighian cell are greatly thickened.

Sterculiaceae. (Mattirolo 401. Caruel 312. Tschirch and Oesterle 267. Brandza 26, 116–117. *pl. 8. f. 9*). In *Sterculia heterophylla* the Malpighian cells form the second layer. The outer portion consists of parenchyma cells with granular contents. The Malpighian cells are greatly elongated, with two light lines. A wide line occupies the upper part of the cell; below it, occur a series of narrow canals, which contain air. The canals extend into the cell-wall. The dark appearance of the cell at this point is due to the contained air. The narrow light line occurs in the upper part of the cell. With chlor-iodide of zinc it assumes a straw color. The lower part of the light line gradually becomes darker, finally bluish-black. Chemically, it appears therefore to differ from the remainder of the cell-wall. It is not, however, typical cellulose. When treated with phloroglucin the light line appears to color slightly, but this is due to the underlying cells. The light line appears in strong contrast with the colored portions. The lower walls of outer parenchyma layers also show the lignin reaction. The lignin test does not quite correspond to Mattirolo's results on *S. platanifolia*, where the reaction is more pronounced. The nutrient layer contains no lignin, except the vascular elements.

Malvaceae. The following writers have discussed the testa or part of it. Duchartre (327); Lohde (396); Strandmark (254); Mattirolo (401); Harz (99, 2:736–750. *f. 34–35*); Bretfeld (306); Junowicz (128); Hanausek (361, *f. 1–5*); Rolfs (435); Brandza (26, 111–115. *pl. 7. f. 9–14. pl. 8. f. 1–5*); Mell (406); Guignard (354, 141–153. *f. 66–80*); Godfrin (71).

The narrow, well-marked light line of *Malvastrum angustum* occurs close to the exterior cell-wall of the Malpighian cell. The light line colors brown changing to a dark brown, with chlor-iodide of zinc. The remainder of the wall also takes on the same dark color. The cell-wall becomes so deeply colored that nothing of its structure can be made out. Phloroglucin colors the light line but slightly, the lower part coloring very rapidly. In general the reactions are the same as those given by Mattirolo for *Gossypium*, except that it is not so deeply colored.

In *Gossypium herbaceum* the narrow light line runs close under the exterior wall. This is followed by a wide clear band which extends above the enlarged cell-cavity in the upper third of the cell. On the addition of chlor-iodide of zinc the whole cell-wall colors yellowish-brown, the lower part much darker, the light line taking on a very pale color. The wide band turns blue except the narrow light line, which remains nearly colorless. Phloroglucin causes the narrow light line to color immediately. It also colors the cell-walls below the cell-cavity, the wide clear band remaining nearly colorless. The narrow light line and the lower part of the Malpighian cell are lignified, while the broad band is made up mostly of cellulose.

Cucurbitaceae. The following writers have studied the testa of this order. Targioni-Tozzetti (257); Strandmark (254); v. Hoehnel (379); Fickel (332); Godfrin (71); Hartwich (368); Harz (99, **2** : 767–824. *f. 39–45*); Mattirolo (401, 20); Michelis (410); Junowicz (128); and Holfert (116).

In *Sicyos angulatus*, the whole upper part above the enlarged cell-cavity is lighter in color than the remainder of the Malpighian cell, except a narrow zone in the lower part of the cell. It is easy to distinguish three light lines. Junowicz found two light lines in *Luffa acutangula*. I have verified this for the species. Mattirolo, who studied the genus carefully, finds a very distinct reaction for lignin with the phloroglucin test. In *Luffa acutangula* the Malpighian cells color very rapidly with phloroglucin and hydrochloric acid, the light line less rapidly. In sections where the reaction has taken place with this reagent, the light line can be made out as a somewhat brighter band. In *Luffa* the cells above the Malpighian layer are also lignified, as well as the cell-walls of the nutrient layer.

In *Sicyos angulatus* the phloroglucin test acts rapidly on the Malpighian cells, except the two upper light lines. These resist its action except for a very slight coloration, so that a nearly hyaline band may be seen stretching across the section, and this after the section has been subjected to this treatment for half an hour. Chlor-iodide of zinc colors the Malpighian cell a yellowish-brown except the narrow light line in the upper part of the cell. This colors a pale yellow and ultimately colors like the other parts of the cell-wall. The wide line colors darker and more rapidly than the cell-wall below. Fickel states that it is not cellulose but that this portion of the cell-wall is lignified. In *Sicyos* the light line is not lignin nor is it cellulose, but it appears to be a cuticularized substance.

Labiatae. The following writers have studied the testa and pericarp. Mattirolo (401); Junowicz (128); Holfert (116); Guignard (354, 67–77. *f. 104–129*); Chatin (313, 86–96. *pl. 6. f. 4–9. pl. 7. f. 1–2. pl. 8. f. 1–5*); Harz (99, 2:866–869). Further references may be found in my paper on *Euphorbia* (416).

The Malpighian cells in this order occur in the wall of the ovary. Junowicz studied *Lallemantia*, and Mattirolo the same genus. *Dracocephalum parviflorum* belongs to the same tribe as *Lallemantia*. It has two light lines, one just underneath the outer row of cells of the pericarp, and one in the lower part of the Malpighian cells. Junowicz found two light lines in *Lallemantia*. With chlor-iodide of zinc the light lines and remainder of the cell-wall color dark brown. With phloroglucin and hydrochloric acid, the light line colors in the characteristic way; the remainder of the cell-wall soon colors in the same way. The whole cell-wall is lignified. The cell-cavity of the Malpighian cell terminates in a number of branched canals. With sulphuric acid and iodine the cell-walls color deep brown, they slowly dissolve in concentrated sulphuric acid.

Convolvulaceae. Several writers have investigated the testa of this order. Lohde (396); Strandmark (254); Mattirolo (401); Harz (99, 2:751. *f. 36–38*); Holfert (116); Kayser (386).

The light lines in *Convolvulaceae* are very distinct. They are shown and described by Kayser, Strandmark, Harz, and Mattirolo. The hard seeds of *Ipomoea Tuba* are provided with two lines, one occurring underneath the exterior wall. The light line is followed by a somewhat darker band in which enlarged pores and a central cell-cavity occur. The darkness is due to contained air. Below this the cell-cavity enlarges. On the addition of chlor-iodide of zinc, the light line colors like the remainder of the cell-wall, brown at first, then changing to a dark brown with a shade of black. The phloroglucin reaction shows that the upper light line colors rose red but slightly, although the exterior walls are somewhat more colored. The upper part of the Malpighian cell colors pale blue, on the addition of this reagent.

The cell-walls of the nutrient layer are lignified, not only where the bundles occur but from the Malpighian cells to the aleurone layer of the endosperm. With sulphuric acid and iodine the cell-walls color blue. The reaction begins around the cell-cavity, and then passes to the light line region, and the lower cells; the light lines appear for a considerable length of time as a lighter band. Several other interesting points should be mentioned in connection with these Malpighian cells. The lower portion is not always blunt, but may be oblique. On making a cross section and placing in chloral hydrate, faint indications of cross walls in the lower part of the cell can be made out. The cross walls of the cells below all end at the same height. When the cells are macerated in Schulze's medium the lower cells may be separated. This has not been clearly indicated by some of the writers who have studied the testa of this order. We may also note the occurrence of an osteosclerid layer above the Malpighian cells, which supports the trichomatous epidermis.

Geraniaceae. The following works bear on this order. Röber (434); Zimmermann (475); Raunkiaer (430); De Toni (324); Brandza (26, 80. *pl. 5. f. 5–8*).

Röber, 1877, was the first one to call attention to the light line in the testa of this order. Raunkiaer, who studied the development and structure of the testa in this order, speaks of the occurrence of a narrow light line. The short Malpighian cells are covered by small epidermal cells, and a layer of parenchyma. The light line is very narrow and might easily be overlooked, at least in *Geranium carolinianum.* Strandmark did not observe it in *G. sanguineum*, although he shows an apparent thickening at this point. A small cell-cavity occurs in the lower part of the cell. With phloroglucin no reaction takes place, although the lower, light-colored, elongated cells color slightly. With chlor-iodide of zinc the cell-walls, including the light line, color brown, and then change to brownish-black, indicating cellulose. With sulphuric acid and iodine the cell-wall colors blue; the light line colors somewhat later. The elongated colorless cells below also color blue.

Rhamnaceae. Malpighian cells are not universal for the order, since Ward and Dunlop (466) do not indicate them for *Rhamnus*, nor does Lindau (394) for this genus. I did not succeed in finding these cells in *Berchemia;* nor does the work of Miers (411) indicate them for the seeds studied by him. The material of *Rhamnus* at my disposal was not satisfactory. Godfrin (71), who studied *Zizyphus vulgaris*, indicates the presence of a light line in the upper part of the Malpighian cells. The testa is very brittle, and it is difficult to get good sections. When these are obtained it is not difficult to make out a wide light line under the cuticle. Godfrin compared it with that found in *Leguminosae*. Structurally it may be compared with the light line found in that order, but it responds very readily to the phloroglucin test, coloring very deeply. The remainder of the cell-wall colors in the same way, but perhaps somewhat less rapidly. It will be seen that the cell-cavity is very much reduced in these cells, and also that the pore-canals are short. The cuticle and cuticularized layers are strongly developed.

The testa of *Ceanothus americanus* is hard and glossy. The greater part consists of the elongated, thick-walled Malpighian cells, which contain very little pigment. The cuticle and cuticularized layers are well developed. The broad light line occurs immediately under the outer lignified cell-wall. On the addition of phloroglucin, the cell-walls of the Malpighian cells, including the light line, color red, but not so deeply as in *Zizyphus*. The light line colors somewhat more tardily than the remainder of the cell-wall. With chlor-iodide of zinc the light line colors yellow at once, and the remainder of the cell-wall soon follows. The color changes to brownish-black. Sulphuric acid and iodine change the cell-wall to a rather dark brown, the light line much lighter in color. The Malpighian cells do not show the lignin reaction in *Adolphia californica*, where the light line is wide and the cell-cavity large. In the Queensland *Alphitonia excelsa* the Malpighian cells are very long, with the cell-walls and light line but slightly lignified.

Nymphaeaceae. Wigand and Dennert (471, 55. *pl. 6. f. 69*), Weberbauer (467, 231. *pl. 8. f. 11*), and Wettstein (468) have studied the order. In *Nelumbo lutea*, as in *Dracocephalum*, the Malpighian cells occur in the wall of the ovary, which is intimately connected with the testa. Wettstein describes it as part of the testa. The considerably elongated, somewhat dark cells have a rather wide light line, which runs across the middle portion. Weberbauer shows longitudinal pores in the region of the light line. A central canal extends from the upper surface down into the wall. With chlor-iodide of zinc the walls of the Malpighian cells color blackish-brown, and the light line also, somewhat later. Phloroglucin shows no lignin reaction. Concentrated sulphuric acid and iodine color the walls deep brown. The cells of the testa and the wall of the ovary are normally blackish-brown because of the presence of pigment.

Scitamineae. The seeds of this order have been studied by many investigators, because of their ecological, physiological, and anatomical peculiarities. I shall refer only to some of the more important papers: Hegelmaier (370); Mattirolo (401); Overhage (415); Tschirch (449. 450); Humphrey (382); Hirsch (373); Kayser (386); Klebs (134); Gris (347); Wittmack (474); Paul (419); Schumann (442); Treub (447a); Pfeiffer (200); Holfert (116); Le Meunier (408); Russow (212).

Canna indica has been studied by numerous investigators. The very hard seed of this species is covered by a waxy material but this does not obscure the numerous stomata which appear as small pits. On removing the outer covering the stomata come more clearly into view. The Malpighian cells are very much elongated, and where the stomata occur are curved in. The light line extends across the cells a little above the middle. With chlor-iodide of zinc the light line and remainder of the cell-wall color yellowish-brown, very slowly changing to a brown-black. The light line is somewhat more refractive at first. Phloroglucin and hydrochloric acid do not affect the cell-wall; sulphuric acid and iodine color it blue.

Marsiliaceae. Much interest has been manifested in an anatomical study of the wall of the sporangium. This structure has not always been emphasized by writers. Of the numerous writers may be mentioned Bischoff (18, **1**: 94, **2**: 110); Mettenius (407); Luerssen (398, **3**: 611, 619. *f. 191*); Strasburger (446b, 123. *pl. 8. f. 147–149*); Valentine (454); Hanstein (363. 365); Braun (305); Russow (212); Mattirolo (401); Campbell (310. 311, 418. *f. 217B*).

The structure of the sporangium has been treated by many writers. An explanation of the light line was offered by Mettenius, who published several monographs on this and related orders of vascular cryptogams. In *Marsilia quadrifolia* the light line extends across the middle of the Malpighian cells. When treated with chlor-iodide of zinc the cell-walls, including the light line, color bluish-black. With phloroglucin and hydrochloric acid no reaction for lignin occurs in any part of the cell. With concentrated sulphuric acid the cell-walls are readily dissolved. With sulphuric acid and iodine the walls color blue. The Malpighian cells are acted upon much more readily than the other parts of the sporangium.

Ecology and Physiology of the Malpighian Cells. — The foregoing review shows that these cells occur in different orders of plants, by no means always closely related. This is an excellent illustration of the fact so frequently noted, that the same structure recurs in different plants for the perpetuity of the species. It is a well-known fact that the seeds of some *Leguminosae* are extremely hard, *e. g.*, *Gymnocladus*, *Gleditschia*, *Mucuna*, and *Physostigma*. The seeds of *Canna* are extremely hard; so are those of *Nelumbo*. We recall also the hard seeds of *Ceanothus* and *Geranium*, and the sporangium of *Marsilia*.

Functionally the testa of leguminous seeds, and the fruit of some others, protect the seed against variations due to changes of moisture. Many of the seeds of *Leguminosae* retain their vitality for a long period of time. De Candolle (49) found that the seeds of *Leguminosae* and *Malvaceae* preserved their vitality longer than those of *Cruciferae, Compositae*, and *Gramineae*. The imbibition of moisture by the seed, and its drying out, greatly lower its germinative energy, hence the importance of a hard covering (162. 165). Leguminous seeds vary with respect to the amount of water they can take up. It was suggested long ago that this was due to a coating of wax (Nobbe 190, 162). Nobbe and Hänlein (191), and Detmer (56) discuss the subject in all its phases.

In view of the more recent researches on the nature of the product found in the cuticle, these earlier opinions are not far out of the way. Von Höhnel (115) states that the capacity for taking up water resides entirely in the Malpighian cells. The seeds of many *Leguminosae*, like *Mucuna urens* and *Cassia Fistula*, can withstand immersion in salt water for some time without impairing their vitality. Darwin (43a) long ago noted the fact for several seeds, including some *Leguminosae*. Martins (167. 168) and Salter (220) indicate the same facts, and Buchwald (35) has shown how admirably the Malpighian cells of *Mucuna* and other leguminous strand plants are protected because of the strong development of these cells. Taubert (258) also shows the same general facts. There can scarcely be a doubt that the thick-walled Malpighian cells with their cuticle enable the seed to thus overcome unfavorable conditions.

It is evident from the above that strand plants may be disseminated by ocean currents and that some North American species, *e. g. Gleditschia* and *Gymnocladus*,* are disseminated by water. Many of the leguminous seeds are disseminated by herbivorous animals. The Malpighian cells here play no small part in protecting the embryo in the passage of the seed along the digestive tract. I have many times seen cattle eat the pods of *Gleditschia triacanthos*. The sweet gummy material is relished. In Central Iowa it is not uncommon to find the honey locust coming up in the streets and around stables. Warder (281) has mentioned this for *Gleditschia*. The seed of *Prosopis juliflora* is largely disseminated by

* The seed alone is probably rarely carried by the water, except freshets, bnt the pods and seeds float.

cattle, as noted by Sargent (221). Cattle feed on the pods when forage is scarce. Some farmers of Texas have proposed to plant the tree extensively so that it may be used for this purpose during the dry season. Its distribution in Texas has, no doubt, been largely brought about by cattle. The excrement forms a most suitable nidus for the germination of the seed. Dr. A. P. Anderson, of South Carolina, informs me that the seed of *Sesbania vesicaria* passes through the digestive tract uninjured.

The wide distribution of *Lespedeza striata* over the Southern States is due, according to Mohr (184), to the excrement of herbivorous animals. I am reliably informed that the seeds of *Cassia Chamaecrista* are disseminated by sheep in Southwestern Iowa. The disseminators in this instance suffered some inconvenience because of the cathartic action of the seed. Grisebach (78) and Morris (184a) have shown that the distribution of *Pithecolobium* in the West Indies is due to herbivorous animals. Morris states that *Acacia arabica* is fed to geese to hasten its germination. The *Ceratonia siliqua* is also disseminated by animals, the hard seed readily passing the digestive tract uninjured (Huth 119). The attractive seeds of *Adenanthera pavonia* L., *Pongamia Corallaria* Miq., and *Abrus precatorius* are disseminated by birds. Buchwald (35) gives a number of additional cases of African seeds disseminated by birds. Dinter (58) states that oxen are very fond of *Acacia giraffae*, and the result is that thousands of young plants spring up in gardens where the manure is scattered. From an ecological standpoint the Malpighian cells certainly have a very important function to perform.

Has the Malpighian layer any other function than that of protection? Mattirolo and Buscalioni (174. 171) state that water enters by way of the micropyle and replaces the air, causing the testa to expand. In some further experiments (175) these writers affirm that when sections are treated with coloring matter it enters through the pore-canals into the underlying cells and tissues of the plant. The light line does not prevent water from entering, but its outward flow is checked. The light line checks transpiration during dry weather. The outer part of the Malpighian cells beyond the light line and below the membrana externa (cuticle) is mucilaginous. This swells, the canals take up the water, and by capillarity it passes into the inner parts of the seed. The light line allows little water to pass. It swells only slightly, but is passively stretched, and in this way causes the enlarging of the canals. When transpiration takes place actively and there is no water to repair the loss, the light line assumes its normal position and the canals close.

Osteosclerids.

Various names have been given to these cells by different writers: Sanduhrzellen (Harz), Säulenzellen (Sempolowski), Trägerzellen (various writers), cellules en sablier (Chalon), cellules de soutien (Marlière), Knochenförmigezellen (Tschirch), colonne (Mattirolo and Buscalioni). For reasons stated above, the classification of Tschirch (265, 1 : 204) has here been followed.

The osteosclerids almost universally accompany the Malpighian cells, in the order *Leguminosae*. Some exceptions occur, as in *Arachis*, where these cells are like those of the nutrient layer. In *Phaseolus vulgaris* the cells are prismatic. In some species they are much longer than in others. The length also varies in different parts of the same seed, being greater towards the hilar region, where the parts are not so strongly compressed. Where the Malpighian cells curve, the osteosclerids gradually become shorter and merge into the star-shaped parenchyma of the hilum. In *Phaseolus lunatus* they are somewhat funnel-shaped. In *Trifolium* and *Medicago* these cells are what the Germans call hourglass-shaped (sanduhrförmige). The cells are here broad at the base with a triangular intercellular space. In other cases the intercellular space is somewhat prismatic and large, as in *Lupinus albus* and *Vicia Faba*. In some species it is much reduced. This is often a question of position, since its size and character vary in the same seed.

The walls are thickened and in some cases marked by longitudinal canals. Some of the German writers refer to these cells as "streifig verdickt" (99, 2 : 612). This character is well marked in some tribes, notably *Trifolieae* and

Vicieae. It is much less marked in such genera as *Gleditschia* and *Phaseolus*. In *Medicago* and *Trifolium* these markings are conspicuous.

The cell-walls give the characteristic reaction for cellulose with chlor-iodide of zinc or with sulphuric acid and iodine. In *Mucuna*, *Gleditschia*, and *Cassia*, lignification does not occur as a rule. Slight lignification occurs in *Baptisia leucophaea* and is recorded for *Baptisia australis* by Mattirolo and Buscalioni (174, *pl. 1. f. 5–19*). The cell contains some protein matters, and in some genera tannin and coloring matter. Some species, notably *Phaseolus vulgaris* and *P. multiflorus*, contain crystals of oxalate of lime. In the closely related *P. lunatus* these crystals have not been found, nor in any of the North American species studied.— Table C.

Nutrient Layer.

Tschirch (265, 1: 301) applied the term "Nährschicht" to the layer following the osteosclerids, to designate its function in the immature seed. In the growing seed the cells of this layer contain not only water but chlorophyll and transitory starch, as I have shown for *Strophostyles pauciflorus*. This starch serves to nourish the growing seed. Holfert (116, 6), who has studied its character in several species, observes that in *Lupinus* it consists of thirty rows of cells. The nutrient layer is by no means confined to this order, as the studies of Holfert as well as those of Schlotterbeck (439) show. As the seed approaches maturity the cells collapse, the cell-cavity appearing as a mere line. In *Lupinus luteus* the layer is reduced one-half, and as much in *Strophostyles*. This layer undoubtedly is also a conductor of elaborated and unelaborated food products. The vascular elements begin at the micropylar end of the seed and extend along the raphe. These cells may also give some mechanical support. In *Mucuna urens* the cells attain considerable development, contain air, and are not compressed. Here they serve to buoy the seed up in water, and thus afford an important means for dissemination. The walls consist of cellulose, as microchemical tests show.

This layer has frequently been called the pigment layer, because of the unusual amount of pigment found here. The general term anthocyanine (Harz 99, **2**: 563) has been applied, and the pigments of several species have received special names. This has been referred to under Malpighian cells. The pigment occurs not only in the cell-wall but in the cavity as well. The coloring matter is formed just preceding maturity when the final products, starch and other reserve materials, are forming. In seeds allowed to mature on the plant this proceeds progressively, but when they are separated it takes place rapidly; in the course of a few minutes the color begins to show in the cells. In sections of *Mucuna pruriens* it rapidly diffuses to the neighboring cells of the cotyledons. The pigment is but slightly soluble in cold water.

Tannin is closely associated with the pigment, and by some has been considered to be a part of it. It likewise occurs in both the cell-walls and cavity. Some tannin has been found in this layer in all the seeds studied, although the quantity is small in some cases.

In some cases protein matter may be made out. Alkaloids like cytisin, robinin, cumarin, and others occur. These also occur in other parts of the seed. In *Melilotus* seeds the cumarin is evident although the seeds have been kept dry for years.

In some cases, calcium oxalate is common in the immature seed, especially in the hilar region; but it is always transitory and disappears when the cells lose their function of supplying nutrient material. The general structure and microchemical reactions are shown in Table D.

Mycotic Layer.

In *Phaseoleae* a well-developed layer of compact cells occurs underneath the nutrient layer. The cells are elongated, thick-walled, and rich in protein. These cells resemble the short, thick-walled hyphae in the sclerotia of some fungi. I found this layer well developed in *Phaseolus multiflorus* and other members of the genus as well as in *Wistaria*. It is figured and briefly described by Tschirch and Oesterle (267), but earlier by Haberlandt (83).

Funiculus and Adjacent Parts.

Under this head I shall discuss the hilum, the hilar groove, micropyle, funiculus, arillus, and arilloid processes (Zwillingshöcker, tuberculi gemini).

Elsewhere the statement was made that the Malpighian cells curve toward the funiculus and that a double row is formed. According to some writers one row belongs to the testa, the other to the funiculus. I have considered both rows as a part of the testa. In each row a light line occurs. The outer row shortens toward the edges where it meets the funiculus; the inner shortens toward the tracheid island.

A section cut across the hilar groove shows a characteristic bundle of tracheids, the so-called "tracheid island" of Tschirch and Oesterle (267). It is oval in outline, connecting at the upper end with the hilar groove (Nabelspalte of the Germans). The tracheids vary in length, being short in the upper and lower parts and much longer in the center. The island is surrounded by several rows of thin-walled cells. The parenchyma in the hilar region has greatly increased and frequently consists of three differentiated parts, rather loosely arranged: (1), thin-walled parenchyma cells, a continuation of the nutrient layer; (2), thicker-walled, star-shaped parenchyma with numerous large intercellular spaces from which the air is not easily expelled; (3), thin-walled, elongated parenchyma surrounding the tracheid island; these cells elongate tangentially at the lower end. In *Mucuna pruriens* twenty rows of these cells occur below the island.

A cross section through the funiculus of *Mucuna pruriens* shows a well-developed fibro-vascular bundle in the center, which consists of phloem and xylem. The elements of the bundle differ in amount in various parts of the funiculus, and in different seeds. This is true of the species studied by Dahmen (43), — *Pisum sativum*, *Vicia Faba*, *Orobus niger*, and *Lupinus luteus*. The phloem consists of the usual sieve cells and their accompanying elements. The xylem in all species thus far studied consists of spirally thickened tracheids. The bundle is surrounded by a parenchyma sheath. The epidermal cells above the rim have their outer walls thickened. The arillate rim in *Mucuna pruriens* consists of thick-walled sclerotic cells which gradually merge into the thinner-walled epidermis. Between the epidermal cells and the parenchyma sheath occur thin-walled parenchyma cells somewhat elongated in the direction of the vascular bundle.

Before maturity the epidermal cells contain a nucleus, cytoplasm with its chlorophyll grains, starch, sugar and asparagin. Dahmen found calcium oxalate rather common, and according to his observation it is rather intimately connected with the formation of cellulose. It accompanies or occurs in combination with a salt of calcium, *e. g.*, calcium glycose. Asparagin is common during the ripening process of the seed in the parenchyma cells of *Mucuna*.

The funiculus is the channel through which the ovule and the developing seed receive their nutrient material, but the vascular elements, according to Dahmen, are not the only channels, as this function may be carried on by the spongy parenchyma and the epidermis. From the funiculus the elaborated products are conducted into the seed by way of the tracheid island. That these substances also pass laterally through the undeveloped Malpighian cells is highly probable. From the tracheid island they can readily pass down, and then tangentially towards the nutrient layer. The elongated, thin-walled parenchyma cells lead directly to the nutrient layer.

The functions of the different parts of this region in the mature seed have been made the subject of papers by Mattirolo and Buscalioni (174), and Pfaefflin (199), who have shown that water passes through the hilar groove; but the latter has found this to be limited. Water passes in readily through the micropylar opening. The Pfaefflin experiments show that the Malpighian cells next to the micropyle take up the greatest amount of water. It seems pretty well demonstrated from the above experiments that the micropyle is hygroscopic in its character, opening and closing according to external conditions. The hilar groove is also hygroscopic. The radicle occurs in a pocket, and is in close proximity to the micropyle. Exchange of gases is accomplished more readily through the micropyle than through the tracheid island.

Mattirolo and Buscalioni ascribe a physiological function to the tracheid island during the early stages of germination.

We may now consider the ecological relations of the structures adjacent to the funiculus. One of the most important of the appendages is the aril. In the immature seed it is intimately connected with the funiculus. The studies of Pfeiffer (200) show that these basal, appendaged structures of the funiculus occur in some *Leguminosae* hitherto regarded as being without an arillus. In *Pisum* it remains attached to the placenta and does not cover the micropyle. In the second type the micropyle is frequently covered or the hilum is surrounded by a thickened border or rim, as in *Mucuna pruriens.* In some of the *Leguminosae* the funiculus, together with the arillus, has an important function to perform in the separation of the seed from the pod (Bachmann 4. Wiesner 285). In a young fertilized ovule of *Pisum* or *Phaseolus* the funiculus is very large, the former rapidly increases in size, and in full active period of growth the latter is small compared with the immature seed. In *Mucuna pruriens* the arillus, the bordered base of the funiculus, becomes an important strengthening organ. It consists of a series of thick-walled sclerotic cells. On the outside these cells are shorter than within, and at the base curve inward. The remainder of the cells curve obliquely upward. The sclerotic rim is wider at the lower end than above, where the cells are shorter and pass into short epidermal cells provided with pores.

The basal part of the funiculus consists of very large thin-walled and highly turgescent parenchyma cells. Immediately above the tracheid island and below these turgescent cells, a few layers of narrow, elongated, and much smaller parenchyma cells occur, which undoubtedly are the conducting elements. Now what takes place during the ripening period? The contents of the parenchyma elements are discharged, the thin-walled, turgescent parenchyma cells collapse, and the funiculus is practically separated from the seed. The final process of complete separation occurs when the pod contracts, owing to drying out. The arillus falls in and helps to pinch the seed off. This pinching-off process is especially marked in the funiculus of *Pisum*. In *Mucuna pruriens* the pinching-off process is similar, although due to the aril. It should be stated, however, that separation from the pod could not be studied on account of its immaturity.

I have given only a few cases and it should not be assumed that the arillus or funiculus has the same mechanical function and structure in all cases, but both organs differ according to the manner of separation. Some of the general anatomical facts are given by Pfeiffer. The arillus is persistent in the seeds of some *Leguminosae*, as in *Pahudia*, *Pithecolobium* and *Copaifera*. The soft, two-lobed arillus of *Pahudia* is eaten by birds.

Inner Integument and Nucellus.

In *Papilionaceae* the inner integument occurs usually as a single row of cells during the earlier stages of development, but is so much compressed in the mature seed that it is difficult to differentiate it from the nucellus. In *Caesalpinieae* the inner integument of the mature seed, although much compressed, may usually be made out more readily. In this suborder it consists of one to four differentiated layers of cells, as in *Gymnocladus*, *Gleditschia*, *Ceratonia*, and *Cassia*.

The nucellus disappears early in the development of the fertilized ovule although it may be present for some time in the chalazal region. As a compressed layer it occurs in *Gymnocladus*, *Lathyrus*, *Vicia*, and *Pisum*. The cells of this layer have lost most of their structure and appear as elongated thread-like bodies. The cells are frequently gelatinized.

Endosperm.

Systematic writers since the time of De Candolle (50. 51) have generally stated that endosperm is absent. Some modern systematic writers have fallen into the same error. Bentham and Hooker (14) state "vulgo parcum v. 0, in generibus paucis copiosum subcartilagineum." Of the *Papilionaceae* these authors say: "albumen saepius parcum v. 0." *Caesalpinieae* "semina varia albumine copioso parco v. 0." Watson and Coulter (283, 122–125) say "mostly without albumen." The *Caesalpinieae* "often with albumen." Britton and Brown

(32, 254, 256, 262) state that endosperm is absent from *Mimosaceae: Caesalpinaceae* with or without endosperm: In *Papilionaceae* seeds mostly without endosperm. Taubert (258, 72, 95) states that the endosperm is usually sparingly developed, or wanting; in some genera, however, present in abundance.

In a discussion of this subject we should not lose sight of the fact that the old test for endosperm, that it could not be recognized with the naked eye, applies to many *Leguminosae.* It would be better in descriptive works to simply say endosperm copious or evident only in cases where it is readily made out. Systematic papers and works are generally a ready means for the identification of plants. It would not help in identification to state that the endosperm in *Vicia* consists of one or two layers of cells, but the question is a very different one when the anatomy of the seed is taken up.

Three writers have made an examination of the seeds of a large number of *Leguminosae* with reference to endosperm. The classic papers of Schleiden and Vogel (234), and Chalon (39) recorded the presence of endosperm in a large number of genera and species. It was also correctly indicated by Duchartre (59), Ralph (204), Baillon (5), Gärtner (67), Bentham (12), Harz (99, 2.) and numerous other monographers.

Many of the species studied by Chalon, and Schleiden and Vogel, had been regarded as exalbuminous, but microscopic study revealed the presence of endosperm in varying amounts. Sempolowski (247. 248), who examined several economic genera, found a small amount of endosperm in the genus *Vicia.* Bischoff (17), and Schleiden and Vogel (234) regarded *Vicia* as exalbuminous. Nobbe (190) regarded *Lupinus* as exalbuminous, but the researches of Sempolowski show that the endosperm is mucilaginous. *Pisum* has always been regarded as exalbuminous and yet it is albuminous. The same writer indicated the presence of endosperm in *Trifolium* in considerable quantity in what Nobbe called the "Quellschichte." In *Ornithopus*, Schleiden and Vogel, Sorauer (250), and Sempolowski indicated endosperm present. The endosperm of *Trigonella foenum-graecum* has long been known. Tschirch uses it to illustrate mucilaginous endosperm in his Angewandte Pflanzenanatomie, but, strangely enough, Wigand (286) considered it to be the inner testa.

The endosperm is not of the same character throughout. In *Gleditschia triacanthos*, *Cassia marylandica*, *Trifolium pratense*, *Medicago sativa*, *Desmodium canescens*, *Lespedeza violacea*, and numerous others, where endosperm is strongly developed, it is differentiated into three parts. Sempolowski indicates this in some species studied by him. Harz likewise indicates this differentiation. In *Lupinus* it consists of a single layer, commonly called the aleurone layer, which, as Guignard (355) has shown, is of wide distribution in plants. It is universal in *Cruciferae* (417) but Strasburger (446a, 339) incorrectly refers to the seed of *Capsella* as being exalbuminous, although he correctly refers to the aleurone layer.

In most of the North American genera studied it is never absent. The aleurone layer is not always sharply marked from the underlying endosperm, *e. g.*, *Astragalus canadensis*. In *Cassia marylandica* and *Gleditschia triacanthos* it is easily distinguishable from the cells underneath and those above. It presents the same characters which I have found in *Cruciferae*, *Rhamnaceae*, *Berberidaceae*, and *Sterculiaceae*. In view of this fact and its wide distribution in other orders, and its great development in seeds with a large amount of endosperm, as in *Gramineae*, *Sterculiaceae*, and *Berberidaceae*, the question naturally arises if this layer has not some function other than the mere storage of reserve proteids. Haberlandt (357) has suggested that the aleurone cells produce diastase during the process of germination and may be classed with the digestion glands of insectivorous plants. The more recent researches of Grüss (350), who has done some excellent work with *Zea mays*, seem to leave no doubt that the aleurone layer is a special secreting organ for the production of diastase. The work of Green (342) partially strengthens the results of Grüss and Haberlandt. Green found that germination was much more rapid when a small amount of endosperm was present.

Reserve Cellulose and mucilaginous endosperm.— Schleiden and Vogel long ago observed that the endosperm of some leguminous seeds becomes mucilaginous on the addition of water. Since then it has been repeatedly observed by Sempolowski, Harz, and Tschirch; and quite recently Nadelmann (185) and Marlière (164) have made a special study of the mucilaginous endosperm. The former studied quite a number of species; the latter, *Ceratonia siliqua*. Nadelmann finds it in all of the tribes except *Geoffrieae* and *Swartzieae*, but not in all genera.

Mucilage* and gums are of wide distribution in the vegetable kingdom, occurring in *Malvaceae* (265, 193. — 64, 93), *Acacia* (265, 213–412), *Symphytum* (265, 203), *Euphorbiaceae* (416, has a bibliography; 339. 99, 2: 831),*Nymphaeaceae* (467), *Linaceae* (319. 335), *Cruciferae* (322. 345.— 417), *Orchidaceae* (265, 194), *Cucurbitaceae* (99, 2: 778–793. 332. 379), *Labiatae* (99, 2: 416. 446), *Acanthaceae* (Bibl. in 416), *Plantaginaceae* (453. 335), *Lythraceae* (317. 353. 390. 426), *Loranthaceae* (314. 85. 154. 370. 400. 385. 393), *Marsiliaceae* (363. 364. 398. 310), *Polemoniaceae* (426. Bibl. in 416. 85), *Algae* (294a. 331, and many others), *Fungi* (307. 308. 301, and many others), *Schizomycetes* (301. 409, and numerous works on the subject).

Its presence in some seeds was long ago observed by Grew (345), and mentioned by De Candolle (322). A glance at Table F shows that the mucilages are not of the same origin nor of the same character. Historically the mucilages and the reserve celluloses are of interest. Schleiden and Vogel (235. 234. 236) applied the term amyloid to the thickened cell-walls found in *Schotia latifolia, Mucuna urens, Tamarindus indicus*, and some others which color blue with iodine. Payen (198, 211–249. *pl. 1*) stated that all cell membranes consisted of cellulose, and that they were isomeric with dextrin, starch, and inulin. He gives the composition as $C_{24}H_{18}O_9H_2O$, and states that it colors blue with sulphuric acid and iodine. Schleiden (232) however thought there were various modifications, and made three divisions, as follows: (1) a form which does not color blue with sulphuric

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* The references given here indicate where the literature may be obtained. From these other references may easily be had.

acid and iodine; (2) amyloid, which colors blue with iodine; (3) plant mucilages, which swell on the addition of water and do not color with iodine. Von Mohl's views (183) did not differ essentially from those expressed by Payen. Nägeli (187, 209) applied the term (1) amyloid to those carbohydrates which color blue with iodine, *e. g.* starch grains, the thick-walled cells of *Schotia*, *Hymenaea*, *Tamarindus*, and *Mucuna*, the endosperm cells of *Calliandra;* (2) the violet modifications of amyloid, as the starch grains in the medullary rays of *Chelidonium*, the endosperm of *Ixia* and *Gladiolus*, the intercellular mucilages of *Florideae* and the mucilages of *Usnea* and *Ramalina;* (3) mesamylin, which colors yellow or not at all, *e. g.*, the bast fibers of many plants like *Linum*, *Cannabis*, and *Urtica divaricata;* (4) disamylum, which is not colored or else colors yellow or intensely golden yellow, or brownish-yellow, *e. g.* endosperm of palms, *Galium*, *Coffea*, and *Strychnos*. Nägeli makes a brief reference to the mucilage of *Leguminosae*.

Frank (335) who investigated the mucilage of several orders of plants, speaks of the reserve cellulose in the endosperm of *Tropaeolum*. The chemical nature of reserve cellulose has been investigated by many writers. Reiss (432), Hoffmeister (377), Miss Cooley (316), Schulze (441), Winterstein (473), Cross and Bevan (320), Zimmermann (294a), Behrens (302), and Tschirch (265, 193–208: *f. 191–208*) treat of the vegetable mucilages.

The gelatinized membranes are distinguished from the ordinary cell-walls by their physical properties. They swell strongly in the presence of water. They agree in their percentage composition with cellulose, $C_6H_{10}O_5$, but they differ from it in their chemical reactions as well as among themselves. Some of them are colored blue with iodine (amyloid), as in the cotyledons of *Tamarindus*, and endosperm of *Tropaeolum*. Others color blue only on the addition of sulphuric acid or chlor-iodide of zinc, as in the thick-walled endosperm cells of *Gymnocladus*, *Gleditschia*, *Lespedeza*, and many others where endosperm is present in the form of reserve cellulose.

Some of the reserve celluloses are colored yellow, others not at all, with iodine. Some are readily soluble in weak acids, as the endosperm of *Liliaceae* and some related orders examined by Miss Cooley.

In *Polygonatum multiflorum* the membrane was dissolved in one minute when acted on by sulphuric acid, diluted with five parts of water. From this it appears to be Schulze's hemicellulose. According to Winterstein this is sometimes associated with amyloid in certain cell-walls. The mucilage of *Astragalus canadensis* and *Gymnocladus* is readily soluble in sulphuric acid, and this is true of many others of the leguminous seed mucilages examined by myself. Some are nearly insoluble in cupra-ammonia. Zimmermann (294a) states that on the addition of nitric acid a part of the gums are changed into oxalic acid, or mucic acid. A part are changed into both kinds of acids.

Cross and Bevan (320) in their recent work on cellulose make the following

Classification of the Celluloses.

A. Typical cellulose and the cellulose group. Cellulose of cotton, flax, and hemp fibers.
 a. *Boehmeria, Marsdenia tenacissima, Calotropis gigantea,* Sunn hemp.
 b. (1) Celluloses of woods and lignified tissues generally.
  (2) Celluloses from cereal straws, esparto.
 c. Pseudo-celluloses.

B. Compound celluloses.
 a. Ligno celluloses. Jute fiber (*Corchorus*).
  (1) Glycodrupose. Sclerotic cells of pear.
  (2) Lignocellulose of cereals. Straw.
  (3) Woods and woody tissues, wood gum. Oak, cherry, cereal straw.
  (4) Coniferous woods.
 b. Pectocelluloses and mucocelluloses.
  (1) Flax cellulose.
  (2) Mucocelluloses. Quince or jalap mucilage.
  (3) Amyloid. *Tamarindus indica, Hymenaea Courbaril, Schotia latifolia, Tropaeolum majus.*
  (4) Lichenin. *Cetraria islandica.*
  (5) Carragheen mucilage. *Fucus crispus.*
 c. Adipocelluloses and cutocelluloses.
  (1) Cork.
  (2) Cutose.

The sources and character of the pectocelluloses have been conveniently arranged by Tschirch (265, 204). His table, with some additions, is added to show the relation which the mucilage of the endosperm and the amyloid of the cotyledons of *Leguminosae* bear to those of other plants.

Classification of Pectocceluloses.

I. Cellulose mucilage. Colors blue with chlor-iodide of zinc and with sulphuric acid and iodine. Insoluble in cupra-ammonia.
   - A. Secondary thickening of cell-walls. Epidermal cell-walls in seed of *Pyrus vulgaris*, *Brassica alba* and other crucifers.
   - B. Mucilaginous intercellular cell-wall substance. Primary cell-wall, *Laminaria* stipites.
   - C. Cell contents, products of distinct mucilage cells. Orchid tubers.

II. True mucilages and gums. Color yellow with iodine, and blue with chlor-iodide of zinc. With hydrochloric acid produce oxalic and mucic acids.
   - A. Secondary thickenings of cell-walls.
     1. Epidermal cell-walls, *Linum* and *Plantago*.
     2. Subepidermal cells, buchu leaves.
     3. Mucilaginous endosperms.
        - a. *Leguminosae: Gymnocladus, Gleditschia, Ceratonia, Lespedeza, Cassia Fistula, C. marylandica, Astragalus, Tetragonolobus, Trifolium, Medicago, Robinia*, etc.
        - b. *Liliaceae: Polygonatum.*
     4. Mucilage of single cells or groups of cells in other tissue. *Althaea*, Cinnamon bark, Frangula bark, flowers of *Tilia*, flowers of *Malvaceae*, seed of Cocoa, *Loranthus*, *Viscum*.
   - B. Outer part of the cell-wall.
     1. Filaments of algae, *Spirogyra*. Hyphae of many fungi.
     2. The gummy resinous product of "colleters," especially young bud scales of *Aesculus*, in which the collagen layer under the cuticle becomes mucilaginous. Also some other epidermal glands. Multicellular glands in which the mucilage occurs in the separating walls of cells: Stems of *Silene*.
   - C. Mucilaginous intercellular cell-wall substance. Primary cell-wall.
     1. Carragheen and other Algae.
     2. The intercellular cell-wall substance of the mucilaginous endosperms, *Tilia* and Mallow flowers. These may in some cases later become mucilaginous.
   - D. Cell contents from distinct mucilage cells. Gum cells in the axial inflorescence of *Hagenia Abyssinica*.
   - E. The contents of entire tissues.
     1. Rhizome of *Symphytum*, *Agropyron repens*.
     2. Succulents, *Aloe*.
     3. Bulbs, *Allium*, *Scilla*.
     4. Algae.
     5. Protective gums, *Acajou*, and *Simaruba*.

F. Contents of schizogenic excretory reservoirs.
  1. *Cycadaceae, Marattiaceae,* some *Sterculiaceae, Araliaceae.*
  2. In schizo-lysigenetic cavities. Rind of *Laminaria* stipites.

G. In lysigenetic passages.
  1. Bark of *Acacia, Moringa, Cochlospermum.*
  2. In bark and woods, *Prunus Cerasus, Herminiera.*
  3. In pith and medullary rays, Tragacanth.
  4. Unknown, gum of *Sterculia urens.*

III. Amyloid. Secondary thickening of cell-walls. Colors blue with iodine. Seeds of *Tropaeolum, Hymenaea Courbaril, Tamarindus, Paeonia, Balsamina, Primulaceae (Primula, Androsace, Anagallis, Glaux), Iris acuta, Cyclamen neapolitanum, Asparagus, Gladiolus segetum,* and cambium of many trees.

It will be seen from the above that plant mucilages are diverse as to origin and occurrence. The mucilage in the testa of *Theobromaceae, Tiliaceae,* and *Sterculiaceae,* was formerly regarded as belonging to cell contents. It arises from the cell membrane, which finally swells and forms a mucilaginous mass. The occurrence of mucilage in the cell is less common than its production from the secondary cell membrane. The mucilage in the parenchyma cells of *Allium Cepa, Scilla maritima,* and the very large mucilage cells of Salep and the tissues of *Symphytum,* the gelatinous cell-walls of *Spirogyra,* the mucilage of *Chondrus crispus,* the mucilaginous cell walls of *Saccharomyces cerevisiae,* and the hyphae of many fungi are all familiar examples of one form and another in which these mucilages occur. Table F shows the reactions of the mucilaginous endosperm in the order *Leguminosae.*

Different opinions have been expressed as to how the material has been laid down. Miss Cooley found in *Liliaceae* and some related orders that it is laid down as secondary structure during the ripening of the seed, and this is also true for *Leguminosae.*

Reserve Cellulose and associated reserve matters.— Tschirch (265, 453) makes the statement that reserve cellulose occurs where the cells of cotyledons are thin-walled and contain no starch or where it is sparingly found. In *Leguminosae* this holds true in general, *e. g. Gymnocladus canadensis, Gleditschia triacanthos, Cassia marylandica, Ceratonia siliqua, Parkinsonia aculeata* and *Robinia Pseudacacia.* In *Trifolium* *pratense* and *T. repens* the reserve cellulose is associated with some starch in the cells of the cotyledons. Miss Cooley (316) found some exceptional cases in *Trillium* and *Paris*, but she observes that the reserve cellulose is small in amount. Reiss (433, 740) first called attention to its occurrence in *Paris quadrifolia*. In *Leguminosae*, as in other plants, the matters occurring associated with reserve cellulose and mucilaginous endosperm are proteids (aleurone grains and the surrounding plasma) and fat. Not only do the proteids occur in the cytoplasm of the endosperm but in the embryo as well. Of their occurrence in the latter we shall speak presently.

USE OF RESERVE CELLULOSE and mucilage.— Sachs (437), in his classic paper on the germination of *Phoenix dactylifera*, showed conclusively that cellulose may be deposited as reserve matter, and that this substance is completely dissolved during the process of germination. Some years later Frank (335, 175) in his researches on mucilages, especially in *Tropaeolum*, indicated the use of reserve cellulose in this plant. Reiss (432. 433), who worked more especially on the chemistry of the reserve celluloses, indicated a similar use in *Chamaerops humilis*, *Asparagus officinalis*, *Allium Cepa*, *Iris pseudo-acorus*, *Foeniculum officinale*, and of the amyloid of *Impatiens Balsamina*, *Paeonia officinalis* and *Cyclamen europaeum*. Miss Cooley (316) studied some additional species among which the following may be mentioned: *Allium ursinum*, *Lilium Martagon*, *Lloydia serotina*, *Smilacina racemosa*, *Belamcanda chinensis*, *Iris sibirica*, *Galanthus nivalis*, etc.

Heinricher (371) suggested that the mucilage in *Impatiens* assists in dissemination, and that the hard substance is a protection against birds. This is, however, very improbable. The mucilage in *Leguminosae* is protected by the hard outer Malpighian cells, and in *Impatiens* it is likewise protected by the tesa. The Malpighian cells repel water for longer or shorter periods in the *Leguminosae*, but this varies in different species. Seeds in which this mucilage attains its greatest development have well and strongly developed Malpighian cells. The Reiss explanation is probably correct, namely, that the plant stores away its food in the most condensed form to save space. Cellulose is much more condensed than starch, proteids or fats.

Ecology of Mucilaginous Seeds. — That mucilage in the seeds of many plants is of considerable use has been abundantly proven. In many small cruciferous seeds, as in *Lepidium*, *Capsella*, and *Sisymbrium*, where the outer walls of the epidermis become mucilaginous, the seeds adhere to any moist object. This must also be the function of mucilage of the smaller seeds in *Euphorbia*, as in *E. glyptosperma*, *E. maculata*, and *E. polygonifolia*, where it is produced in considerable quantity.

The objection may be raised for large cruciferous and *Euphorbia* seeds that they do not adhere very readily, because of their size. In proportion to their size the quantity of mucilage in these larger seeds is much less than in the smaller, at least so far as I have investigated the species of *Euphorbia* represented in Gray's Manual (416) and the *Cruciferae* of the same work (417). The larger seeds are disseminated in other ways. The smaller seeds of *Ruellia*, with copious mucilaginous spiricles, are as easily disseminated as the seeds of *Euphorbia*. The mechanism for dispersal of seeds in *Arceuthobium* is well known. The seed when ejected is thrown several feet, the viscid mucilage in which it is embedded causing it to stick to the bark of a tree when brought in contact with it.

Grütter (353) has suggested that the mucilage hairs of *Lythraceae* are for the purpose of fastening the seed to the soil, which is doubtless true to some extent for cruciferous seeds, *Salvia*, *Ruellia*, and *Euphorbia*. Köhne (390) suggests that the mucilage of the seeds of *Lythraceae* renders them more buoyant. In *Nymphaea* and *Euryale* the arillus becomes mucilaginous and floats on the water. The mucilage of the well known squirting cucumber becomes highly turgescent because of its great affinity for water and when mature the stalk separates from the plant and thus scatters the seed. It is a little more difficult to explain the use of mucilage in the cucumber as we now know it. It is not improbable that it served a similar purpose at one time. The mucilage formed in the cross layer of cells at the base of petioles, and the consequent deliquescence, help to separate leaves from the stem. The mucilage produced at the tip of the aerial roots of corn no doubt helps to fasten them to the ground (367).

In none of these cases can the mucilage be compared with that found in *Leguminosae*. It has been suggested that the mucilage in *Loranthus* and *Viscum* is a water reservoir (400, 85). That it may also serve the same purpose in leguminous seeds can hardly be doubted. When once the water passes the Malpighian cells and reaches the endosperm the latter has a great affinity for it and additional amounts are taken up readily. In this respect it may be compared with the mucilage cells of succulents (452. 463). After the endosperm has taken up water the aleurone layer secretes a ferment which dissolves the cell-walls, and the soluble material is conveyed to the embryo.

Embryo.

The embryos of the seeds of our *Leguminosae* are extremely variable from a structural standpoint. In the common food *Leguminosae*, *e. g.*, *Pisum*, *Vicia*, and *Phaseolus*, the outer row of cells is somewhat elongated. The outer walls are thickened and with no intercellular spaces between the cells of the first row. The cells below are larger, with small intercellular spaces at their angles. In *Phaseolus multiflorus* the structure is essentially the same except that the cell-walls of the interior are provided with pores. The intercellular spaces are large. In many of the *Phaseoleae* there are several rows of elongated, palisade-like cells on the superior face. In *Pisum* they are absent from both the inferior and superior faces. In others the cells below are spongy. The spongy structure makes the seed light so that it can easily float (Buchwald 35). Van Tieghem (274. 275) also cites similar cases. In *Astragalus canadensis* the outer row of cells is considerably smaller, the outer walls are thickened, the cells within are much longer with small intercellular spaces. The character and form of these cells are shown in Table G. The microchemical reactions of cell-walls and contents are shown in Table E.

The reserve material varies not only in tribes but in related genera. In general, however, tribes are quite constant. In

Vicieae and *Phaseoleae* the reserve food consists largely of carbohydrates in the form of starch, and proteids in the form of aleurone grains. In *Caesalpinieae* the reserve food occurs in the form of proteids and fat; in *Trifolium*, as starch, proteids and fat; in *Glycine hispida*, largely as fat and proteids; in *Schotia*, *Tamarindus*, and *Lupinus*, as reserve cellulose, proteids and fat. The proteid of leguminous seeds seems to vary greatly. In the pea it is similar to globulin, and is soluble in a two per cent. solution of common salt. The common bean has a proteid known as phaseolin.*

In the Soy bean, the proteids vary from 32 to 44 per cent. (99, 2 : 697). Green (75) has shown that there exists in lupine seed a proteolytic ferment which converts the proteids during germination into pepsin, leucin, and asparagin.

The starch grains are extremely variable, being small in *Trifolium*, relatively large in *Pisum* and *Phaseolus*, and very large in *Rhynchosia erythroides* (Schleiden and Vogel 234), and other species. The starch grains of many of our common species are described and figured in many text-books. Additional facts are given by Nägeli (187), Löhr (150), and Klotz (135). The economic legumes are considered by Harz (99) and Tschirch and Oesterle (267).

Fat, which is commonly present, is embedded in the so-called oil plasma and is an important reserve food. In the Soy bean it varies from 13 to 20 per cent. (Harz 99, 2 : 697).

The cell-walls of some *Leguminosae*, as *Lupinus* sp., *Bianca scandens*, *Centrosema virginianum*, *Clitoria brasiliana*, *C. Mariana*, *Copaifera officinalis*, *Hymenaea Courbaril*, *Swartzia Langsdorfii*, *Goodia*, *Cyanospermum*, *Erythrina ascoca*, and *Tamarindus*, are thickened, in some species more than in others. This reserve material is an amyloid in most cases. Its relation to the thick-walled reserve cellulose is shown in Table E, under endosperm. Two opposite views are held in regard to the reserve nature of this material in *Lupinus albus*. Nadelmann (185) concludes that the cell-walls enter into solution, and his figures show progressive changes. Elfert

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* For a discussion of these products see Griessmayer (77), Osborn & Campbell (194), Green (74), Harz (99, 2), König (136), Jenkins & Winton (125), and a host of chemical writers both American and European.

(61) maintains that the thick-walled cells are not consumed during germination and hence are not of reserve cellulose. This is true, according to Elfert, for *L. luteus*, *L. albus*, and *L. angustifolius*. The same writer, however, refers to the thick-walled cells in the cotyledons of *Impatiens* as reserve material. It is possible that the ferment capable of dissolving the thick walls of cotyledons is similar to Green's (75) amylolytic ferment. Its occurrence and use in *Schotia* were noted by Godfrin (72), but this fact was known to Schleiden and Vogel (234). The facts are brought together by Tschirch (265, 453). Judging from the studies of Harz (99, 2 : 594) and Kumm (138) the cell-walls are generally thickened in the genus *Lupinus*. In our own species studied, the walls are but slightly thickened, usually but little more than in *Phaseolus*.

We may also note the occurrence of chromatophores as well as a nucleus and nucleolus in the cells of cotyledons. The procambial vessels are readily made out in sections treated with chloral hydrate. These cell-walls are not lignified in *Astragalus canadensis*, *Mucuna pruriens*, *Baptisia leucophaea*, *Cassia marylandica*, and *Tamarindus indicus*, nor generally for *Leguminosae* so far as I know. In but few cases has any differentiation taken place in the species that I have studied except *Gymnocladus canadensis* and *Vicia Faba*. According to Klotz (135) spiral tracheids occur in *Pisum*. It may be interesting to observe that in some seeds like *Mucuna* and *Physostigma* a hollow cavity occurs between the two cotyledons. This is to aid dissemination, according to Buchwald (35).

ANATOMICAL CHARACTERS OF SEEDS

From a Systematic Standpoint.

Histological structures of seeds or parts of various drugs have long been brought into requisition as aids for the recognition of plants. This is well shown in numerous works dealing with subjects of pharmacognosy. That anatomical characters of different organs may have a much wider use has also been abundantly shown. Some early attempts were made to use anatomical characters from the standpoint of taxonomy by Fournier (334), 1865, who has given details of structure of different members of the order *Cruciferae*, especially *Sisymbrium*, in which good characters were found. Fournier has published several additional papers on the use of anatomical characters in classification. A. Prunet has reviewed the more important works on anatomy with reference to classification, in Bonnier's Revue Générale de Botanique. Robinson (434a, 137), who has recently studied our North American species of the order, says in regard to *Sisymbrium:* "The pubescence, which, if all species of both continents are considered, passes from simple or occasionally forked hairs to dense stellation, fails to give a really satisfactory generic distinction." Dennert's (384) paper indicates one general type of stem structure and then gives an artificial key based on the presence or absence of hard bast, showing no parallelism between related genera. This order *Cruciferae* is one in which anatomical characters are much used, but not always in a satisfactory way.

The minute structure of the leaves of *Coniferae* has long been used as an aid in the diagnosis of species, as in the works of Engelmann (330), McNab (403–405), Coulter and Rose (318), Penhallow (421) and others. The diagnostic value of anatomical characters has been verified by many students. Duval-Jouve (328), 1870, discussed the anatomical characters of *Gramineae* with special reference to *Agropyron*. His researches show some most striking differences. Hackel, in his monograph on European species of the genus *Festuca*, states that the form of the cross-section of the lamina affords a valuable means for distinguishing some species, though one must cautiously consider variation with reference to soil and climate. Many of our manual species afford valuable anatomical characters, as the work of Mrs. Hansen (418) shows for *Sporobolus*. Holm (381), in a series of valuable papers, describes numerous North American grasses and finds most distinctive characters. Ball (299) has established the same fact for *Eragrostis*, and Miss Sirrine (446), for *Panicum*. It is not necessary to cite further facts in this order.

J. Vesque (458–461) has published several very important papers on the application of anatomy to classification. His researches were not confined to a single order but covered *Anonaceae*, *Berberidaceae*, *Bixaceae*, *Calycanthaceae*, *Canellaceae*, *Capparidaceae*, *Caryophyllaceae*, *Cistaceae*, *Cruciferae*, *Dilleniaceae*, *Frankeniaceae*, *Fouquierieae*, *Magnoliaceae*, *Menispermaceae*, *Papaveraceae*, *Pittosporaceae*, *Polygalaceae*, *Portulacaceae*, *Ranunculaceae*, *Resedaceae*, *Sarraceniaceae*, *Tamaricaceae*, *Tremandraceae*, and *Violaceae*. Various characters are used, such as simple or compound trichomes, presence or absence of crystals, stomata, and fibro-vascular bundles. In a general comprehensive paper on the subject (460. 461) his views have not changed materially, and he adds that taxonomists often fail to obtain all of the material in collections necessary to properly describe a species, hence the descriptions are imperfect. These uncertainties will cease when anatomy occupies a place of merit in the system of classification. This calls to mind the work of Solereder (444), who shows that Masters wrongly determined a *Bragantia* sent to him by Dr. Cleghorn. Solereder states that its anatomical structure shows that it does not belong to the order *Aristolochiaceae* but probably to the *Menispermaceae*. In his exhaustive account of the anatomical characters of this order he includes the structure of the seeds of many species.

The nature of the epidermis, stomata, secretion glands, and sclerenchyma affords valuable diagnostic characters. Radlkofer (429), 1883, emphasized the importance of this application of the anatomy of plants, in his address before the Munich Academy. Pax (420), who has studied the order *Euphorbiaceae*, established an anatomical system. His studies supported the divisions made by Müller instead of the Baillon, and Bentham and Hooker systems. Quite recently, Van Tieghem (457) has made use of some anatomical characters in the special part of his work Éléments de Botanique.

The *Leguminosae* have been investigated by Jaensch (383), Warburg (465), Schube (440), and Van Tieghem (455). Jännicke (384) found eight types of stem in *Papilionaceae*. It was not difficult to find characters of systematic value. In *Vicia* and *Trifolium*, large genera, different characters occur; these are, however, not always so marked as the gross morphological characters. Louis Petit* has published an important monograph (422) on the anatomical characters of the petioles of various orders including representative tribes of the order *Leguminosae.*

Pritzel (428) has recently published a paper of considerable length on anatomical characters, especially in the endosperm of Parietales. According to Pritzel the arrangement of the Parietales is an unnatural one. The *Chlaenaceae* are excluded. Pritzel finds that their anatomical characters show them to be allies of the *Malvaceae* and not *Theaceae*, where the order was placed by Engler and Prantl in their Natürlichen Pflanzenfamilien.

If differential points of this kind occur in related species, what of hybrids? It has been shown that hybrids show intermediate characters. Wettstein (469) has found excellent characters in the hybrids of some conifers, *Pinus* and *Juniperus.* He determined that *J. Kanitzii* had its origin in *J. sabinoides* × *J. communis.* The anatomical structure confirmed his previous opinion.† Intermediate anatomical characters also occur in *Pyrus Malus* × *P. toringo.* If these characters occur and repeat themselves in the hybrid offspring it would certainly seem probable that anatomy should often show some most tangible characters.

This investigation as applied to seeds reveals many excellent characters, shown to better advantage by Harz (99, 2 : 555–1350) than by any other writer. Godfrin (71) was most conservative in expressing the opinion that anatomical seed characters could not be or are of but little value for systematic purposes. I expressed a conservative view in a paper on the structure of the testa in *Euphorbiaceae* (416), to which Gram (339. 340) takes exception. I recognized differences, and

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* The author has a good bibliography and refers to the work of Trécul on the same order, and Acqua, whose work is said to agree with Petit. McAlpine and Renfrey (402) made a careful study of the *Eucalyptus* petiole, in which they found valuable characters. In a later work, 1889, Petit (Nouvelles recherches sur le pétiole des phanérogames. Acts. Soc. Linnéenne de Bordeaux **1889.** Separate, 50, *pl. 1–4*), discusses additional species, including several more *Leguminosae.*

† The Wettstein paper gives some of the literature. Other cases are cited by Kerner-Oliver, Natural History of Plants.

called attention to the mucilaginous spiricles; somewhat similar to those in *Ruellia*, in some sections of the genus *Euphorbia*, and the total absence of mucilage in some species. In some recent studies of the testa of *Berberidaceae*, I have found some excellent generic characters; but very closely related species it is often difficult to differentiate. Subgenera in *Berberis* are easily separated. In *Cruciferae* (417) I have also found some excellent characters. In studies of this kind one is likely to fall into the same errors that the older systematic botanists did, from not having had an abundance of material to work over. Some botanists have drawn inferences from a study of scant material and few species.

In examining the seeds of *Leguminosae*, my studies have been confined to genera and subgenera. Some excellent anatomical characters have been found in tribes and some genera, but it is often difficult to differentiate closely related species. This statement, however, applies equally well to morphological characters. Size is by no means always a good criterion in anatomy, as Schumann (443) has shown, or in taxonomy. The seed is, however, more constant under natural conditions than are the vegetative organs. The general characters of seeds often afford most valuable characters. These have been used in many cases, as in Engelmann's work on *Euphorbia* and numerous other systematic works. Quite recently Cunningham (321) has proposed to use the seed characters of *Plantago*, and Wiegand the same for *Galium*.

SYSTEMATIC.

At first I contemplated only a study of the genera represented in Gray's Manual (6th ed.). As the work progressed, however, it seemed best to include all of our economic genera and a few additional from the South and Southwest.

For synonymy, the Kew Index has been followed, as this agrees essentially with the names applied to the species in Gray's Manual (6th ed.). In the genus *Phaseolus* I have followed Watson. Where these two systems disagree the synonymy is placed in parenthesis. Since Britton and Brown's Illustrated Flora of the United States and Canada is in general use I have placed the names used by them in parenthesis where their system differs from Gray and the Kew Index.

The material for this study was obtained from the herbarium of the Missouri Botanical Garden, the herbarium of the Iowa State College of Agriculture and Mechanic Arts, and the seed collection of the United States Department of Agriculture. I have given a general synopsis of the tribes and genera at the end of the descriptive part of the work.

PAPILIONACEAE — Podalyrieae.

BAPTISIA, Vent.

BAPTISIA LEUCANTHA, Torr. & Gray.

Pl. VII. f. 1. Pl. XXXV. f. 12.

Testa well developed, somewhat irregular on surface, total thickness on sides 398.4 μ.

*Malpighian.** Cuticle forms a continuous narrow layer, darker in color than the remainder of the cell. The outer portion of the cell-wall separates from the remainder of the wall where the conical projections occur. Light line narrow, occurs underneath the cuticle, and colors blue with chlor-iodide of zinc.

Malpighian cells 117.6 μ. long, somewhat longer toward the hilar region, with a shorter second row. In a surface view the cells are usually six-sided with a central "canal" and 5 to 6 lateral branches; rarely more than two terminal branches. Cell-cavity gradually tapers toward the upper end. The pores extend a little less than one-third of the way down. Pigment and some tannin present; slight lignification below cuticle, and in lower portion of the cell-wall where it joins the osteosclerid.

Osteosclerid. Cells vary in length, mostly 30–80 μ, wider in lower part than above, with large intercellular spaces in the hilar region where the cells are much larger and transformed into star-shaped parenchyma. Cell-walls are colored

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* I have employed Malpighian for Malpighian layer, Osteosclerid for osteosclerid layer, Nutrient for nutrient layer, and Mycotic for mycotic layer.

brown, and contain tannin; also a small amount of lignin in the upper part of the wall.

Nutrient. This layer varies in width, and is compressed. On the addition of chloral hydrate four layers of thin-walled cells may be made out, although the number of rows varies in different parts of the section. In the hilar region these number from 12 to 15 and are of lighter color than elsewhere. The lower parts of the layer contain the vascular elements, also thick-walled cells. In the hilar region these cells are thinner walled, and darker in color than in the remaining lower parts of this layer.

Endosperm. This is differentiated into three parts. In the first row or aleurone layer, the cells are thick-walled, nearly isodiametric, filled with granular contents, fat, and albuminoids. Cell-walls mucilaginous and cells contain protein. In the lower portion of the endosperm the cells are elongated and thick-walled, with a narrow cavity.

Embryo. The first row of cells much smaller, forming a compact, continuous layer; cells below larger, except the procambial cells. All of the cells are filled with protein grains and fat. Starch absent. Chloral hydrate causes the fat to come out in the form of globules.— (St. Louis, Eggert, Mo. Bot. Gard.)

Thermopsis, R. Br.

Thermopsis caroliniana, M. A. Curtis.

Pl. VII. f. 2–2c.

Different layers of testa quite uniformly developed, except in the hilar region. On sides 298.8 μ thick.

Malpighian. Yellowish cuticle uniformly covering these cells, 1.4 μ in thickness; this readily separates from the remainder of the Malpighian cell; the latter is 75.6 μ in length with a rather wide light line extending across the cells underneath the cuticle. Several canals extend into the cell-walls from the surface. Cell-cavity has its greatest width at the lower end, gradually tapering upwards into a narrow line; contains some protein grains, which color brown with chlor-iodide of zinc. Cell-walls color blue.

Osteosclerid. The cells are quite uniform on sides, 28 μ in length, on ends larger. Cell-walls thickened, with large intercellular spaces. These are much larger at the ends of the seeds. Cell-cavity contains a small amount of protoplasmic matter which colors brown with chlor-iodide of zinc.

Nutrient. This is much compressed, consisting of from three to six layers of cells. Cell-walls mostly thickened; these as well as the contents are brown, owing to the presence of pigment and tannin. Spiral ducts also occur.

Endosperm. This is well developed, especially on the sides, the zone gradually narrows toward the end. First row of cells smaller, thick-walled; contain fat and protein. Followed by two to seven layers of thick-walled cells constituting the reserve cellulose. The cells contain protein and fat. The cell-walls at the lower end are not so thick. A layer of thick-walled, elongated cells with protein matter joins the cotyledons. On the addition of chlor-iodide of zinc the cell-walls of the endosperm color blue.

Embryo. First row of cells continuous, with a large nucleus. Outer cell-walls thicker than the lateral and inner. Remaining cells larger, rather thick-walled, with conspicuous intercellular spaces. All of the cells contain aleurone grains and fat. A few small starch grains occur in the cells below the outer row. — (Buckley, Mo. Bot. Gard.)

THERMOPSIS RHOMBIFOLIA, Richards.

The seeds of the specimen studied were not mature.

Malpighian. Cells variable, longest 95.2 μ in length. Light line runs close under the cuticle and is not strongly marked in specimen.

Osteosclerid. Cells with large intercellular spaces.

Nutrient. Cells nearly coloress, thin-walled and irregular.

Endosperm. Walls of cells but slightly thickened. — (Mont., Mo. Bot. Garden.)

PAPILIONACEAE — Sophoreae.

CLADRASTIS, Raf.

CLADRASTIS TINCTORIA, Raf. (*C. lutea*, Michx., Koch.)

Pl. X. f. 5.

Testa not strongly developed, total thickness on sides 131.6 μ.

Malpighian. Cells 64.4 μ in length. The cuticle forms a continuous layer; light line close under the cuticle; cell-wall between cuticle and light line differentiated into a clearer portion. Cell-walls and cells nearly colorless. Cell-cavity filled with small protein grains which on the addition of chlor-iodide of zinc are colored brown; the cell-wall colors blue. Several canals project into the walls from the cuticularized layer. The Malpighian cells are somewhat elongated in a surface view; canals extend from the central cavity and branch toward the periphery. The branches number from six to seven.

Osteosclerid. Cells as wide above as below, with large intercellular spaces. The cell-walls are thickened and with chlor-iodide of zinc color blue. The contents are granular and color brown with iodine.

Nutrient. Not strongly developed; consists of three or four layers of strongly compressed cells. The cell-walls are not greatly thickened. This layer contains the yellow pigment and the fibro-vascular elements. Not infrequently the layer is differentiated into two parts.

Endosperm. This attains considerable size on the sides of the seeds. It is divided into three parts. In the first or aleurone layer, the cell-walls are greatly thickened; the cells are filled with fat and protein. The aleurone layer uniformly surrounds the remainder of the endosperm. The second portion consists of very thick-walled cells with large pore canals; this varies in width from a few to fifteen cells. The cells contain aleurone grains and fat. On the addition of chloral hydrate the fat collects in drops. The lower part of the endosperm is made up of two or three rows of thick-walled cells, much longer than broad, containing protein grains. The cell-walls of the endosperm color blue with chlor-iodide of zinc; contents color brown with iodine.

Embryo. The first row of cells forms a continuous layer. The outer cell-walls are more strongly thickened than the lateral. The remaining cells are thinner-walled and much larger, irregular, with intercellular spaces. The cells are filled with aleurone grains and fat, but no starch. Iodine colors the aleurone grains brown; the cell-walls are colored blue with chlor-iodide of zinc.

SOPHORA, L.

SOPHORA SERICEA, Nutt.

Pl. X. f. 1–1c.

Testa developed quite uniformly. The testa with endosperm measures 196.4 μ in thickness, but on the sides of the seed, 243 μ; near the ends of the seed, only 64.8 μ.

Malpighian. The cuticle forms a continuous thin layer; the narrow light line runs close under the cuticle just below the cuticularized layer. The cavity is large at the lower end, gradually tapering upward. Several canals project into the thickened cell-wall; these are of different lengths. With chlor-iodide of zinc the cuticularized layer colors darker blue than the remainder of the cell-wall, corresponding to the structure found by Schips for some other leguminous seeds.

Osteosclerid. Cells are thick-walled, with large intercellular spaces, quite uniform as to size. Walls slightly brownish in color, and coloring blue with chlor-iodide of zinc.

Nutrient. The cells are much compressed, rather thick-walled, and vary somewhat in size. Cells of the lower portion are smaller than in the upper. This layer contains the brown pigment and the vascular elements. The walls color blue with chlor-iodide of zinc.

Endosperm. This is well developed and is differentiated into three parts: (1) aleurone layer, (2) reserve cellulose, (3) narrow, elongated, thick-walled cells. Cells of the aleurone layer are uniform throughout and surround the entire reserve cellulose. The cells contain fat and protein grains. The cell-walls in part consist of reserve cellulose which is mucilaginous. Cell-walls are thickened and provided with large pore-canals. The cell-cavity contains protein. In the layer next to the cotyledons the walls are thickened and elongated; the cells are small and contain some protein matter. On the addition of chlor-iodide of zinc the outer portion of the cell-wall immediately colors blue. The inner portion of the cell-wall takes a lighter shade of blue.

Embryo. The first row of cells forms a continuous row; the outer wall is thickened. The cell-walls below the outer row have minute canals. The cells contain protein, fat, and minute starch grains. The cell-walls consist of cellulose.

PAPILIONACEAE — Genisteae.

CROTALARIA, Dill.

CROTALARIA SAGITTALIS, L.

Pl. X. f. 4.

The testa not strongly developed; endosperm 196 μ in thickness. From Nadelmann's studies it appears that in *Crotalaria verrucosa* the horny endosperm is well developed, being four and one-half times as wide as the testa. The aleurone layer contains fat and aleurone grains. The cells of the embryo contain protein and fat but no starch.

Malpighian. The cells are prismatic in surface view, 9.8 μ across, with five to six canals. In cross-sections they are 84 μ long. The cuticle forms a continuous layer; with longitudinal canals projecting into the cells; these extend down through the upper part of the cell-wall and the cuticularized substance; this layer is lighter in color than the rest of the cell-wall, and separates from the remainder of the cell in the form of a band. The narrow light line occurs close under the cuticularized layer. The cell-cavity is narrow and gradually tapers upward; it contains some protein matter. The cell-wall consists of cellulose.

Osteosclerid. The walls are thickened. Cells wide in the lower part and narrowing upwards, with large intercellular spaces. Cells contain protein.

Nutrient. Consists of radially elongated cells, which are slightly compressed. Walls of medium thickness, slightly colored.

Endosperm. Not strongly developed. The cells of the aleurone layer large, containing protein. Two layers follow this, the cells very much compressed, and somewhat radially elongated. The lower portion radially elongated, of thick-walled cells. All of the cells contain protein and fat.

Embryo. Cells of outer row smaller; those adjoining the endosperm thicker-walled, the inner part with thinner walls. The remaining cells of the embryo larger. All of the cells filled with protein. Starch is absent.

Genista, L.

Detailed studies of the anatomy of the seeds have been made by Nadelmann and Harz, and brief notes by Tschirch. Schleiden and Vogel long ago pointed out that "Dyer's Green Weed" is albuminous. On the addition of water the horny endosperm becomes mucilaginous. The cell-walls are greatly thickened. Schleiden and Vogel as well as Nadelmann and Harz speak of a green pigment found in the Malpighian cells, to which the name of "Seladon green" has been given.

Genista tinctoria, L.

Pl. X. f. 2–2c.

Total thickness of testa including endosperm 332 μ; strongest development on the sides.

Malpighian. Cells forming a continuous layer but in sections frequently showing rifts; uniformly developed, 56 μ in length and wide in proportion to their length; cell-cavity conspicuously wider at the lower end then gradually tapering upward; several canals projecting into the cell-wall; light line under the cuticularized portion, narrow but very bright.

Osteosclerid. Cells short, thick-walled, nearly of equal width except the constriction in the middle, which results in a large intercellular space between the contiguous cells; slightly colored and somewhat compressed.

Nutrient. Layer somewhat compressed, more conspicuous than the osteosclerid layer; walls colored greenish, containing protein grains and coloring matter.

Endosperm. Width varying in different parts of the seed but attaining its maximum development on the sides between caulicle and the chalazal region, and measuring 132.4 μ. Aleurone cells thick-walled and conspicuously different from the remainder of the endosperm (stated by Nadelmann not to be different). Cells containing fat and protein grains. The horny endosperm on the addition of water becoming mucilaginous. Cells with well-developed pore-canals and the cell-walls differentiated into two parts. On the addition of chloriodide of zinc, the primary cell-wall colors blue rather slowly.

The inner colors blue more rapidly. Protein grains are abundant in cavity. The lower portion of the endosperm consists of elongated, thick-walled cells; this layer surrouuds the whole embryo.

Embryo. First row of cells much smaller than those within, nearly isodiametric, outer walls thickened; the lateral thin-walled, apparently striated, with longitudinal bars. Several rows of palisade cells on superior face of cotyledon. Cells packed with fat and protein grains. Walls color blue with chlor-iodide of zinc. Starch is absent.

LABURNUM, L.

LABURNUM ANAGYROIDES, Medic.

For allied species see *Cytisus scoparius*. — *Pl. X. f. 3.*

According to Nadelmann the structure of *Cytisus Laburnum* approaches that of *Tetragonolobus purpureus.* The Malpighian cells carry a green pigment; the endosperm reaches its greatest development laterally. The tertiary membrane of the reserve cellulose in the endosperm colors blue. The seeds of Scotch Broom were formerly considered medicinal. Husemann and Marmé isolated a very poisonous, strongly basic alkaloid, cytisin.

Testa and endosperm measure 431.6 μ in thickness, the endosperm being more than twice as thick as the testa. The testa differs little from that of *Genista tinctoria.*

Malpighian. Cuticle forms a continuous layer and in mounted specimens shows fissures; light line is a narrow zone close under the cuticle. Cell-cavity wide at lower end, gradually tapering upward. Canals extend down into the cell-wall for more than one-third of the distance.

Nutrient. This layer is moderately developed, consisting of four rows of irregular, thin-walled cells, containing some protein grains.

Endosperm. The first layer of cells, the aleurone, with thick walls, containing protein grains and fat; the remainder of the endosperm, except the portion next to the embryo, consists of thick-walled cells with pore-canals; these contain some fat and protein grains.

LUPINUS, Tourn. L.

The seeds of the genus *Lupinus* have long been subjects of study. Malpighi described the seeds of Lupinus as follows: "Eadem ferè configuratio occurrit in pisis & lupinis 302, quorum secundina exterior solitis fistulis A componitur, horizontaliter ductis, quibus multiplices substant ordines utriculorum B, vario situ & figurâ constantes, hisque contento semini cellula paratur." Later studies were made by Schleiden and Vogel, who found a small amount of endosperm present in the seeds of *L. tomentosus*, DC., and *L. polyphyllus*, Lind. (*L. macrophyllus*, Benth.). Endosperm, according to Harz, is absent in most of the species, although found in small quantity in *L. hirsutus*, L. and *L. angustifolius*, L. Sempolowski found that in the last species it consists of a single row of strongly compressed cells which on the addition of water become mucilaginous. Nadelmann states that *L. polyphyllus*, Lind., and *L. luteus*, L., have a small amount of endosperm while all the others studied by him are without endosperm. In *Leguminosae* the reserve cellulose is, as a rule, found in the endosperm but in several species of *Lupinus* it occurs in the cotyledons where it is an amyloid. In germination these secondary cell-walls become soluble, the primary wall remaining. Nadelmann has studied the process in detail and concludes that the secondary thickening of walls in cotyledons constitutes reserve material. The loss of this substance in cotyledons is progressive with the appearance of starch and chlorophyll. The seeds of lupines are highly nitrogenous, containing as much as 42.21 per cent. of albuminoids. These albuminoids in lupine seeds have been called conglutin by Ritthausen. The cellulose is said to occur in two forms by Siewert, useful and useless so far as the food of the plant is concerned. In cotyledons and seed coats 11.45 per cent. is of the useful, and 13.24 per cent. of the useless. Seeds of lupines contain a bitter alkaloid known as lupinin which is readily soluble in cold water. Several insoluble alkaloids also occur; among these, perhaps, small quantities of coniin. In different species the alkaloids vary from 0.02 to 1.0 per cent.

LUPINUS PUSILLUS, Pursh.

Pl. IX. f. 1–2.

The testa and endosperm of this species measure 124.5 μ. The Malpighian cells and the osteosclerids are well and uniformly developed.

Malpighian. Cuticle forms a continuous well-developed layer; cells 49.80 μ long; a broad light line occurs close under the cuticularized layer. This layer colors blue with chlor-iodide of zinc. The cell-cavity is large at the lower end with wavy margins, and contains small protein grains.

Osteosclerid. The cells have thick walls and a narrow cavity, as wide above as below, and a constriction in the middle with a large intercellular space between the cells.

Nutrient. This layer is but slightly developed; cell-walls thin, and the cell-cavity contains granular contents; it contains the vascular elements.

Endosperm. In the seed studied, which was not quite mature, development had progressed far enough to show thick-walled cells such as usually occur in the lower part of the endosperm next to the cotyledons.

Embryo. Cells of first row with greatly thickened exterior cell-walls; lateral walls thinner; the remaining cells with thinner walls, irregular, with intercellular spaces. Palisade cells of superior face consist of three to four rows. Cells rich in protein which is contained in the oil plasma. Starch is absent. — (Wyoming, Nelson, Mo. Bot. Gard.)

LUPINUS ALBUS, L.

Pl. IX. f. 3.

Testa strongly developed, 415 μ thick. The pigment layer is much more conspicuous than in *L. pusillus.*

Malpighian. Cells are 140 μ long. The cuticle forms a continuous, somewhat irregular layer; broad light line below the cuticle. Several light lines have been distinguished in this species. Numerous canals project into the cell-wall; cavities irregular, very narrow, containing granular contents. Below the middle the wall shows a deflection, hence appearing somewhat geniculate.

Osteosclerid. Layer strongly developed; thick walls with a constriction in the middle ; large intercellular spaces between the cells. Upper and lower bars equal.

Nutrient. Cells thin-walled, irregular, of a yellow color; lower part of the layer is much compressed and the cell-walls contain more pigment. The layer also contains the vascular elements.

Endosperm. Though the statement is made that the seed of this species is without endosperm, it has the same amount as *L. pusillus.* The cells are elongated, thick-walled, containing protein grains.

Embryo. The cell-walls thickened, consisting of reserve cellulose. Starch absent. Cells contain fat and protein.

PAPILIONACEAE — Trifolieae.

The tribe *Trifolieae* is represented by three genera in the Manual, only one of which is indigenous, *Trifolium.* Most of the species of this genus are introduced. An anatomical study of the seed gives additional reason for maintaining this as a distinct tribe. The cotyledons contain small starch grains and most of the species are provided with endosperm. The osteosclerids, so far as they have been studied, are longitudinally striated in all of the genera examined, *Trifolium, Ononis, Trigonella, Medicago,* and *Melilotus.* The African and Asiatic *Parochetus* has not been examined. The walls are not longitudinally striated in the related *Lotus* and *Tetragonolobus.*

TRIFOLIUM, Tourn.

There are several excellent accounts of the structure of the seed, by Sempolowski, Harz, and Nadelmann. My studies are inserted here so that the species may be compared with others. Endosperm is well developed but variable in thickness. Walls of the testa and endosperm 91 μ to 140 μ in thickness.

TRIFOLIUM PRATENSE, L.

Pl. IX. f. 6–6b.

Malpighian. Cells are 56 μ long. Surface view of the cells prismatic; pore-canals extending from the center; the cuticle forms a continuous even layer, darker in color than the cuticularized layer. In cross-section several canals may be seen extending into the cell-walls from the cuticle. A narrow light line runs close under the cuticularized layer. The cell-cavity gradually tapers upward and is filled with protein grains, tannin, occasionally a large chromatophore, and pigment. The cell-walls color blue with chlor-iodide of zinc.

Osteosclerid. Layer is well developed; cells uniform in width above and below, as a rule with but a slight constriction in the middle, 12.6 μ to 14 μ in length and 11.2 μ in width. Cell-walls greatly thickened and provided with longitudinal canals. In sectional view these plainly indicate that they are minute canals, and not folds as has been stated by some writers.

Nutrient. The layer is unequally developed, from a few rows of cells to a dozen; the cells are thin-walled, somewhat elongated, compressed, walls colored greenish or purplish.

Endosperm. The cells of the aleurone layer are longer than broad, thick-walled, containing fat and protein grains. In the underlying cells the primary cell-wall is thin, the remainder of the cell-wall constitutes the reserve cellulose and is greatly thickened. Following this is a layer consisting of one or two rows of elongated, thick-walled cells.

Embryo. The first cells of the first row are smaller; cell-walls which join the endosperm are thickened; the remaining cells are larger except the procambial vessels. All of the cells contain an abundance of protein, small starch grains, and fat. Cell-walls color blue with chlor-iodide of zinc. — (St. Louis, L. H. Pammel.)

TRIFOLIUM REFLEXUM, L.

Pl. IX. f. 5.

Testa and endosperm 100–110 μ in thickness. The Malpighian cells nearly as long as endosperm and remainder of testa are thick.

Malpighian. Quite uniformly developed, 42–44 μ in length. Cuticle thickened irregularly; cuticle and cuticularized part separating readily from the remainder of the cells; the light line rather wide under the cuticularized layer; several canals projecting into the cell-wall; cells containing protein grains and pigment, and a conspicuous large chromatophore in their lower part.

Osteosclerid. Cells with a broad base and hence a triangular space under the Malpighian cells; cell-walls thickened, and marked with longitudinal striae, the canals. The cells contain some protein grains.

Nutrient. Layer but slightly developed. Parenchyma cells contain pigment, the cell-walls also pigmented.

Endosperm. Aleurone layer of elongated, thick-walled cells, containing fat and protein, followed by one or more layers of larger cells with similar walls, and, in the lower part, by thick-walled, elongated cells with a narrow cavity. These cells contain some protein grains.

Embryo. First row of cells smaller; the outer walls next to the endosperm thickened. These cells have an abundance of protein and fat but no starch. The remaining cells are as in *T. pratense*, but with less starch. — (Shannon Co., Mo., B. F. Bush, Mo. Bot. Gard.)

TRIFOLIUM AGRARIUM, L.

Pl. IX. f. 2b.

Testa and endosperm 60–90 μ in thickness. In the narrow portions the Malpighian cells are nearly as long as the remainder of the testa is thick. The endosperm much the same as in *T. reflexum* except that the round chromatophores are near the center and the intercellular space between the osteosclerids is smaller. The cell-walls of the aleurone layer are thicker. The mucilaginous reserve cellulose of the endosperm is thick-walled. The cells of the embryo as in other species; numerous small starch grains and aleurone grains. The walls of the outer row of cells greatly thickened. — (Nantucket, Mass., Fritchey).

MELILOTUS, Tourn.

The species of this genus are much alike and in their anatomical structure resemble *Medicago.* The osteosclerids have conspicuous longitudinal canals. The aleurone layer is well-marked, and there are variable amounts of additional endosperm. The testa and cotyledons contain cumarin which also occurs in other genera, as in Tonka bean, and in *Hierochloe*, a grass.

MELILOTUS ALBA, Lam.

Pl. VIII. f. 2.

Testa and endosperm vary in thickness, average 75 μ. Malpighian cells as long as the thickness of the endosperm and remainder of testa.

Malpighian. Cuticle wavy and well developed; the cuticularized layer below with small, conical projections, those of two adjoining cells meeting at the middle lamella of the lateral walls, giving the layer the appearance of consisting of cone-like projections. These cones are also connected with the small pore-canals. This cuticularized layer is highly refractive. The light line consists of a narrow but distinct refractive zone below the conical layer. The refractive zone colors blue with chlor-iodide of zinc. The whole upper part is, however, more or less refractive. The remainder of the cell-wall contains pigment and is colored blue with chlor-iodide of zinc; the cuticularized layer as well as the conical layer colors blue. Small canals project into the walls, in some cases extending beyond the light line. The chromatophores are irregularly distributed in the cell-cavity, some near the base, others in the center.

Osteosclerid. Cells with a broad base and a small triangular intercellular space above; longitudinal pore-canals in the upper part of the cell, but these do not extend its entire length.

Nutrient. This layer is much compressed; consists of thin-walled cells, divided into two parts; cell-walls of lower part thicker. Both layers contain pigment and tannin, the upper more than the lower. Cell-walls consist of cellulose.

Endosperm. The aleurone layer is quite distinct; the cells are rectangular; cell-walls made up of cellulose. The walls of the remainder of the endosperm, except where it joins the embryo, are thick, consisting of mucilaginous reserve cellulose. Cells of the internal layer of the endosperm thick-walled, elongated, containing some protein grains and fat.

Embryo. Cells of the exterior walls of first row thickened; they are smaller than those below. All of the cells contain fat, protein grains, and small starch grains. Procambial vessels well developed. — (St. Louis, Eggert, Mo. Bot. Gard.)

MELILOTUS OFFICINALIS, Lam.

Pl. VIII. f. 1–1c. 5.

Testa with endosperm varying from 260 to 300 μ in thickness. The Malpighian cells of this species are longer than in *M. alba*, and also more abundantly supplied with pigment. The conical projections are longer. The osteosclerids are longer and nearly as wide above as below. The longitudinal canals as conspicuous and well-developed as in that species. Cells of the nutrient layer, especially in the lower part, are abundantly supplied with pigment and some tannin. The walls of the aleurone cells are thick; the mucilaginous reserve cellulose and the thick-walled, elongated cells are not essentially different from the last species. It also agrees with it with respect to the embryo. — (Europe, Reverch., Mo. Bot. Gard.)

MEDICAGO, Tourn.

The seeds of several species have been studied by Harz, Sempolowski and Nadelmann. The Malpighian cells are provided with conical projections as in *Melilotus*. The walls of the osteosclerids are longitudinally striated; the aleurone layer is very different from the mucilaginous endosperm. The species are not exalbuminous as stated by Lubbock. The seeds, especially of *M. sativa*, are variously colored. Haberlandt, according to Harz, has determined that the lighter colored seeds germinate more rapidly and better than the dark-colored ones.

MEDICAGO SATIVA, L.

Pl. XXIV. f. 1–1h.

Testa uniform in thickness; endosperm variable.

Malpighian. Cells are 39–42 μ long. Cuticule forms a continuous surface; cuticularized layer with conical projections, conspicuous. With chlor-iodide of zinc it colors blue; the cuticle, brown. The light line occurs below the cuticularized layer; this colors light blue with the same reagent. The remainder of the cell-wall colors dark blue. The cell-cavity is large at the base, gradually tapering upward, small in the upper part of the cell. Several pores in each cell project into the wall beyond the light line. Normally the cells as a whole are colored yellow, and contain tannin and some yellow pigment.

Osteosclerid. Cells usually have a broad base and an intercellular space in the upper part of the layer. Cells in sections from the lateral part of seed are more or less I-shaped with the base somewhat broader, longitudinally striated. Cell-walls are colorless and with chlor-iodide of zinc color blue. Some tannin present in the cell-cavity.

Nutrient. This layer is differentiated into two parts, and is much compressed. Cells elongated, thin-walled; Cells in the lower part are smaller and contain much more pigment and tannin than those of upper portion. Walls color blue with chlor-iodide of zinc. Vascular elements occur in this layer; these give the lignin reaction. Parenchyma cells surrounding the root cap also give reaction for lignin.

Endosperm. Aleurone cells very distinct; containing fat and protein. The thick walls consist of reserve cellulose; walls color but faintly with sulphuric acid and iodine; the non-mucilaginous cells below are elongated, thick-walled, with a small cavity in which some protein remnants occur. In water the walls become mucilaginous, and change in outline. Internal layer of endosperm of several rows of thick-walled, elongated cells.

Embryo. The cells of the first row are smaller, with thick exterior walls which color blue with chlor-iodide of zinc. The cells below are larger and somewhat irregular; the portion of the cotyledon next to the endosperm becomes the under side when the seed germinates; the cells of the interior rows where the cotyledons meet, except the outer, are elongated, palisade-like, and become true palisade cells in germination, composing two or more rows which are closely connected with the procambial vessels. Cells of the cotyledons densely filled with protein and fat.

Iodine alone does not show starch grains because obscured by fat and protein. When treated with chlor-iodide of zinc small round or elliptical starch grains show.— (S. W. Texas, Heller, Mo. Bot. Gard.)

MEDICAGO LUPULINA, L.

Pl. VIII. f. 3–3b. Pl. XXIV. f. 2–2b.

Testa and endosperm well developed, 245 μ in thickness on sides. More than half of this thickness consists of endosperm.

Malpighian. Cells 40–42 μ in length. Cuticle slightly irregular; underneath the cuticle a light-colored area with conical projections, as in *Melilotus*, but somewhat more prominent. With chlor-iodide of zinc this rapidly colors blue. It corresponds to the mucilaginous "membrana interna" of Mattirolo and Buscalioni, and, as shown by Schips, is chemically differentiated from the cuticle and remainder of the cell-wall. The conical layer is highly refractive. The light line occurs below the conical layer and colors blue soon after the addition of chlor-iodide of zinc. The cell-cavity is broadest at the base, gradually tapering upward. A large chromatophore occurs at the base or near the middle of the cell-cavity. In colored seed some pigment occurs in the cavity as well as considerable amounts in the walls. Small pore-canals occur in the upper part of the cell-wall. The cell-walls color blue more slowly with chlor-iodide of zinc than the cuticularized layer.

Osteosclerid. Cells broad at the base, with conspicuous longitudinal pores; intercellular spaces below the Malpighian cells triangular; walls colored brownish; cells containing pigment and tannin.

Nutrient. This layer is much compressed, and differentiated into two parts; cells elongated, rather thin-walled; those in the lower portion carry a great deal of pigment, and are much more compressed that the upper portion.

Endosperm. The endosperm is of unequal development, laterally as much as 150 μ in thickness. Harz gives the thickness as 250 μ. Cells of the aleurone layer rectangular, thick-walled, and filled with fat and protein grains. This layer is followed by reserve cellulose. The primary wall persists when treated with weak solvents. The walls, except the primary, color blue with chlor-iodide of zinc. The inner portion of the endosperm consists of thick-walled, elongated cells.

Embryo. Cells of the first row smaller than those below; exterior walls thickened more than the lateral; all of the cell-walls consist of cellulose. Cells contain fat and protein grains; starch grains do not occur, though Harz says they are usually abundant. In several specimens examined I was unable to find starch, neither when potassium hydrate nor weak sulphuric acid was used with the iodine. — (Fritchey, Craighead, Penn., Mo. Bot. Gard.)

MEDICAGO DENTICULATA, Willd.

Pl. VIII. f. 4–4b.

The seeds of this species agree with those of *M. lupulina.*

Malpighian cells 35–38 μ long; the narrow light line occurs below the conical layer; the chromatophores are absent.

Osteosclerids 16–18 μ long; longitudinal striae well marked. Cross sections show beyond a doubt that these striae are canals. The nutrient layer is much compressed.

Aleurone layer of endosperm as in *M. lupulina.* The mucilaginous reserve cellulose not so strongly developed as in the last species. Treatment with iodine gives no reaction for starch; nor do blue grains appear when treated with weak sulphuric acid and iodine, or potash and iodine. An abundance of fat and protein grains occur in the cells. Walls of the reserve cellulose color light blue. Malpighian cells a darker blue. — (Todaro, Palermo, Herb. Curling-Joad, Mo. Bot. Gard.)

PAPILIONACEAE — Loteae.

HOSACKIA, Dougl. (*Lotus*, L.)

Anatomically the seed of this genus is very distinct from *Medicago, Trifolium, Melilotus,* and *Ononis.* It shows considerable affinity to *Lotus* and *Tetragonolobus.*

HOSACKIA PURSHIANA, Benth. (*Lotus americanus,* Nutt., Bisch.)

Pl. XI. f. 5–5b.

Testa conspicuously brown-colored, uniform. Endosperm somewhat variable in thickness. Endosperm and testa 180 μ in thickness.

Malpighian. Cuticle strongly developed; outer surface roughened; followed by a rather wide cuticularized layer. Conical layer not very evident. Narrow light line immediately below the cuticularized portion. Cell-cavity large at the base, and terminating rather abruptly. Cell-walls and contents brown in color; cells containing tannin. The walls color blue with chlor-iodide of zinc.

Osteosclerid. Cells short, as wide above as below; I-shaped, prominently constricted. Longitudinal striae of walls not evident.

Nutrient. Layer differentiated into two parts, the upper more compressed than the lower; cells thin-walled, the walls deeply colored.

Endosperm. Cells of the aleurone layer thick-walled, in outline more or less quadrangular; containing fat and protein grains. The mucilaginous reserve cellulose layer follows; this is of variable thickness and agrees with *Lotus corniculatus.* The conspicuous pore-canals connect with adjoining cells. The internal part of the endosperm is more or less compressed and consists of thick-walled, elongated cells; the narrow lumen contains proteid substances.

Embryo. The exterior walls of the first row of cells are thicker than the lateral. This layer forms a continuous row of nearly isodiametric cells. The cells below are somewhat irregular, with intercellular spaces in the angles. Superior face with two rows of palisade cells. Cells contain fat and protein grains but no starch. — (Oklahoma, Waugh, Mo. Bot. Gard.)

PAPILIONACEAE — Galegeae.

PSORALEA, L.

The Malpighian cells are well developed. Conical layer absent. Osteosclerids thick-walled, non-striated; endosperm but sparingly developed.

PSORALEA MELILOTOIDES, Michx. (*P. pedunculata*, Mill., Vail.)

Pl. XI. f. 4–4c.

Testa and endosperm of variable thickness, 160–200 μ, most of this variation being found in the testa.

Malpighian. Cuticle thick, slightly irregular; sections show rifts due to the collapse of the mucilaginous cuticularized layer. The narrow light line forms a distinct zone below the cuticularized portion; both color blue with chlor-iodide of zinc soon after the addition of the reagent. Pore-canals elongated, extending nearly to the lower part of the cell. Cell-cavity small, containing a brown pigment, the walls colored in the same way.

Osteosclerid. The thick-walled cells are elongated; upper and lower bars nearly equal; cell-cavity small; intercellular spaces elongated. Cells contain protein grains and pigment.

Nutrient. Layer unequally developed; cells are elongated, and loosely arranged. Pigment abundant in the lower part of layer; the vascular elements also occur in this portion. The walls color blue with chlor-iodide of zinc.

Endosperm. Sparingly developed. Aleurone cells somewhat elongated, containing fat and protein grains; this layer is followed by the mucilaginous reserve cellulose, consisting of large cells. Internal part of endosperm consists of thick-walled, elongated cells, containing protein grains and fat.

Embryo. Exterior walls of the first row of cells are thickened. The cells, which are smaller than those below, form a continuous row. The interior cells are more loosely arranged. The superior face consists of three to four rows of palisade cells. The cells contain fat, protein, and small starch grains. Cell-walls color blue with chlor-iodide of zinc. — (N. W. B., Mo. Bot. Gard.)

PSORALEA TENUIFLORA, Pursh.

Pl. XI. f. 1–1b.

Testa well developed, 260–275 μ in thickness. The species characterized by a conspicuous mycotic layer; endosperm nearly wanting.

Malpighian. Cuticle forms a thick, even layer; the well-marked light line occurs close under the cuticle; numerous pores project into the nearly colorless wall. Cell-cavity irregular, constricted, containing one or more chromatophores of different sizes, protein, and but a small amount of pigment.

Osteosclerid. Cell-walls greatly thickened; upper and lower bars wide, 30–35 μ; constriction 20–25 μ. Cells contain protein grains, pigment, and tannin, and in color contrast decidedly with the Malpighian layer.

Nutrient. The cells of this layer are thick-walled, elongated, and brown, containing protein grains and tannin. It also contains the vascular elements.

Mycotic. This layer is of considerable thickness, measuring 56 μ; the cells are nearly colorless, thick-walled, and elongated; the elongated, tortuous cells are partially separated by numerous small intercellular spaces.

Nucellus. Although the development has not been studied, I believe that the layer below the mycotic is the nucellus. The cells are very dark in color — much more so than the usual nutrient layer or nucellus.

Embryo. The outer row of cells continuous; no intercellular spaces; exterior walls thickened; much smaller (14–16 $\times$ 9.8–14 μ) than the parenchyma below; these measure 33.6–56 $\times$ 33–19.6 μ. Cells contain fat and protein grains but no starch.

PSORALEA CUSPIDATA, Pursh.

Pl. XI. f. 2–2b.

Testa and small layer of endosperm 99.6–23.4 μ in thickness, nearly colorless, as in *P. tenuiflora.* Osteosclerids also agree with those of that species. The nutrient layer with a great deal of pigment. Endosperm sparingly developed. First row of cells of embryo somewhat elongated, with thin lateral walls; exterior walls thicker. Interior cells of embryo thin-walled, with a triangular intercellular space at the angles. — (Kerrville, Texas, Heller, Mo. Bot. Gard.)

AMORPHA, L.

Schleiden and Vogel called attention to the mucilaginous endosperm of this genus. The species here studied mostly agree as to their Malpighian cells. The endosperm is unequally developed.

AMORPHA CANESCENS, Nutt.

Pl. XI. f. 3–3b.

Testa and endosperm vary in thickness, 95–232 μ, mostly due to the endosperm, which reaches its greatest development on the sides at the two ends.

Malpighian. Cells are 58–62 μ in length. Cuticle is uniform in thickness, well-developed; cuticularized layer not conspicuous, but on the addition of chlor-iodide of zinc it colors a faint blue; the light line occurs underneath the cuticularized layer and colors blue on the addition of the same reagent, as does the remainder of the cell-wall, though less promptly. From this and other species it is evident that the light line contains less foreign matter than the remainder of the cell-wall. The cell-cavity is broad and irregular at the lower end but gradually tapers upward. It contains protein grains, pigment, and tannin.

Osteosclerid. Cells are elongated, thick-walled; the cross bars somewhat unequal; upper portion smaller; large intercellular spaces between the cells.

Nutrient. This layer is differentiated into two parts. Walls are not greatly thickened, and color blue with chlor-iodide of zinc. The lower part of the layer takes on a deeper color than the upper. Contents and walls color brown with the same reagent.

Endosperm. Varies in thickness. Aleurone cells thick-walled. The reserve cellulose cells are thick-walled, and become mucilaginous on the addition of water. The walls color blue with chlor-iodide of zinc. The primary cell-wall is thin. The compressed internal layer consists of thick-walled, elongated cells with a small lumen. The reserve cellulose cells and internal layer contain fat and protein.

Embryo. The exterior walls of the first row of cells are thickened. The internal cells are smaller and thinner-walled than those of the outer row. The walls color blue with chlor-iodide of zinc. Cells contain fat, protein, and small starch grains. — (St. Louis, Eggert, Mo. Bot. Gard.)

AMORPHA FRUTICOSA, L.

Pl. XI. f. 6–6b.

This species was studied by Schleiden and Vogel, who reported the presence of endosperm. It does not differ essentially from *A. canescens.* Testa and endosperm 150–335 μ in thickness, this variation largely due to the endosperm. Malpighian cells 66.4 μ long; pore-canals well marked. Chlor-iodide of zinc colors the cell-walls blue very rapidly. Osteosclerids variable as to length, thick-walled, with large intercellular spaces. Cells contain pigment, tannin, and protein. Nutrient layer as in the last species. Cells of the aleurone layer of the endosperm are thick-walled. Cells of the reserve cellulose with small pore-canals. Walls differentiated into three distinct layers. The secondary wall colors blue rapidly, the inner is more refractive and colors violet blue. The cells contain fat and protein. The internal layer of the endosperm as in *A. canescens*. The cells of the embryo agree with those of the last species as to structure, but starch was not found. — (N. C., Mo. Bot. Gard.)

DALEA, L. (*Parosela*, Cav.)

Early studies of some species of this genus were made by Schleiden and Vogel. All of the species, thus far studied, contain endosperm. The embryo contains no starch. Pigment abundant in the nutrient layer.

DALEA ALOPECUROIDES, Willd. (*Parosela Dalea*, L., Britt.) *Pl. XII. f. 1–1b. 5.*

Testa and endosperm from 150–265 μ in thickness. Variation is mostly due to the endosperm, which reaches its greatest development laterally.

Malpighian. Cells are 36.4 μ in length. Cuticle prominent; cuticularized layer not conspicuous; narrow light line near the cuticle; pores prominent, extending into the walls beyond the light line. Cell cavity broad at the base, containing protein grains.

Osteosclerid. Cells thick-walled, lighter in color than the Malpighian layer. They contain pigment, tannin, and protein.

Nutrient. This layer is compressed and the cells are elongated. Walls color blue with chlor-iodide of zinc. Brown pigment abundant in the vascular region.

Endosperm. Aleurone cells nearly isodiametric, containing fat and protein; most of the endosperm consisting of reserve cellulose, with prominent pore-canals; the internal layer consisting of elongated, thick-walled cells, with cell-cavity much reduced.

Embryo. First row of cells of embryo smaller than underlying, with thickened outer walls. Cells below with small intercellular spaces. Reserve material consists of fat and protein grains; starch is absent. — (Iowa City, Iowa, Hitchcock, Mo. Bot. Gard.)

DALEA LAXIFLORA, Pursh. (*Parosela enneandra*, Nutt., Britt.) *Pl. XII. f. 7.*

Structurally much as in the last species. Testa and endosperm 130–180 μ in thickness. Malpighian cells 42 μ long; nearly colorless, with a large chromatophore in the cell-cavity; several conspicuous pore-canals extend from the surface, somewhat beyond the light line. Osteosclerids are thick-walled and wide at the base; the intercellular space larger above than below. Nutrient layer as in the last species. The aleurone cells of endosperm thick-walled; the remainder, except the internal layer, consists of mucilaginous reserve cellulose. Embryo as in *D. alopecuroides.*

PETALOSTEMON, Michx. (*Kuhnistera*, Lam.)

Seeds with endosperm. Malpighian cells yellowish, with a large cavity and chromatophores.

PETALOSTEMON CANDIDUS, Michx. (*K. candida*, Willd., Kze.) *Pl. XII. f. 6–6b. Pl. XXVIII. f. 4–4c.*

Testa and endosperm 90–110 μ in thickness, the latter variable, but strongly developed laterally.

Malpighian. Cells are 33 μ long. Cuticle forms an even and continuous layer; the cuticularized layer follows; light line occurs under a narrow and distinct zone of the latter; pore-canals project into the walls somewhat below the light line but are indistinct. Cell-cavity wide at the base and gradually tapering upward; the large chromatophore colors brown with iodine. Cell-walls color blue with chlor-iodide of zinc; the light line pale blue with the same reagent. The cuticularized layer readily separates above the light line.

Osteosclerid. Cells are elongated, with long intercellular spaces; the walls are greatly thickened and color blue with chlor-iodide of zinc; the contents color brown.

Nutrient. In seed not quite mature this layer consists of five to ten rows of thin-walled cells containing an abundance of pigment and tannin. Chlor-iodide of zinc colors the walls blue; the vascular elements are lignified.

Endosperm. The first layer of cells, aleurone, thick-walled, followed by a variable amount of mucilaginous reserve cellulose. Cells in lower part are thick-walled and elongated; the reserve cellulose readily dissolves in mineral acids. Contents color brown with iodine, and the walls, blue with chlor-iodide of zinc.

Embryo. Exterior walls of the epidermal cells thicker than the lateral; these cells are nearly isodiametric; the underlying, somewhat larger; palisade cells nearly wanting on the ends of the seed but well developed in the middle lateral portion. Fat and protein present; starch wanting. — (St. Louis, Eggert, Mo. Bot. Gard.)

PETALOSTEMON VIOLACEUS, Michx. (*K. purpurea*, Vent., Macm.)

Pl. XII. f. 3.

Testa and endosperm as in the last species. Malpighian cells somewhat shorter than in *P. candidus.* Light line close under the cuticle; the central canal in cross section shows numerous branches. Osteosclerids smaller towards the narrow part of the seed, and thick-walled. Nutrient layer compressed, carrying a great deal of pigment. — (Indian Territory, Bush, Mo. Bot. Gard.)

TEPHROSIA, Pers. (*Cracca*, L.)

The species studied have endosperm, chromatophores in Malpighian cells, and an abundance of fat and protein grains in the cotyledons; starch is wanting. Lysigenetic canals present in embryo, and usually an abundance of crystals of oxalate of lime in the cotyledons.

TEPHROSIA VIRGINIANA, Pers. (*Cracca virginiana*, L.)

Pl. XII. f. 4–4c. Pl. XIX. f. 1–1f.

Testa and endosperm 117 μ in thickness. Malpighian cells make up nearly half of the thickness of the testa and endosperm.

Malpighian. Cells 56 μ in length. Cuticle an even continuous layer, followed by the cuticularized zone; the narrow light line lies below the latter. Several pore-canals extend into the walls for nearly one-third of the length of the cell. Cell-cavity large at the base, containing protein grains and a chromatophore, the latter variable as to position.

Osteosclerid. Cells are thick-walled; upper and lower bars nearly equal. Intercellular spaces nearly square. Walls color blue with chlor-iodide of zinc.

Nutrient. Layer much compressed, variable as to thickness. The cells are rather thick-walled; only a small amount of pigment, tannin and some protein grains present; vascular elements occur in the lower part. Cell-walls color blue with chlor-iodide of zinc.

Endosperm. Aleurone layer nearly isodiametric, thick-walled, containing protein. This layer is followed by two or three rows of thick-walled cells with pore-canals. Walls color blue with chlor-iodide of zinc. The internal layer of the reserve cellulose consists of thick-walled, elongated cells with narrow lumen. Cells contain fat and protein.

Embryo. Cells of the first row with exterior walls thickened, smaller than those below; the interior cells are irregular with intercellular spaces; walls color blue with chlor-iodide of zinc. All of the cells of the embryo contain fat and protein, but little or no starch, and an abundance of compound crystals of oxalate of lime. Two rows of well-developed palisade parenchyma cells occur on the upper surface of seed during germination, or on the side next to the endosperm; the first row more compactly arranged than the rows below; the third is much interrupted because of the lysigenetic reservoirs. With a hand-lens one is able to readily distinguish spherical glistening bodies, somewhat irregularly distributed; higher magnification shows that these glistening bodies are surrounded by the parenchyma of the cotyledons. In some places these cells are shorter than the remaining parenchyma. In a longitudinal section these bodies are about of the same diameter. The development has not been studied, but in some sections it is possible to make out cells with a central globular body. I do not hesitate in calling the secretion reservoir lysigenetic. Tests were made with alcannin for resin, but with negative results. The same reagent indicated an abundance of fat in the other cells of the cotyledons. Check tests were made for other resins, so that there seems to be good evidence that the secretion is not resinous, nor does it contain fatty acids since potash does not destroy the contents of the reservoir, but with long-continued action they turn yellowish; with this reagent the reservoir colors a somewhat deeper brown. The reservoir failed to give tannin reaction with ferric-chloride. Sulphuric acid and iodine color the contents brown, the wall blue. Chlor-iodide of zinc acts in the same way. Delafield's haematoxylin colors the walls violet, but no action takes place on the contents of the reservoir. Fuchsine colors the contents of the reservoir bright red, much deeper than the contents of the parenchyma.

Whether the secretion receptacle may not contain poisonous products, such as have been found in young branches and flowers of *Tephrosia toxicaria*, and other species (Radlkofer and Rosenthal), I have been unable to determine. An examination of herbarium material did not reveal similar structures in parts of the plants examined (petiole). The reservoirs of the peduncle resemble those figured for *Copaifera Langsdorfii* by Tschirch in his Angewandte Pflanzenanatomie. The peduncle of *Tephrosia virginiana* has similar secretion reservoirs. *Apios tuberosa*, according to Gray's Manual, contains latex. There is no evidence that the substance in *Tephrosia* is latex. The walls of the surrounding cells color blue with chlor-iodide of zinc.—(St. Louis, Eggert, Mo. Bot. Gard.)

TEPHROSIA HISPIDULA Pers. (*Cracca hispidula*, Michx., K.) *Pl. XII. f. 2a.*

Testa and endosperm are somewhat more strongly developed than in the last species, 154 μ in thickness. Malpighian cells 50 μ long; light line a sharp zone below the cuticularized layer; the cavity irregular in the lower part of the cell. Osteosclerids are longer than in *T. virginiana;* the intercellular spaces are very long. An abundance of pigment is found in the lower part of the nutrient layer. The aleurone cells are elongated, and the cell-walls of the endosperm do not color blue rapidly with chlor-iodide of zinc. Oxalate of lime crystals are abundant in the embryo, but the reservoirs for secretion are not so numerous as in the last species. These lysigenetic reservoirs also occur in the cotyledons of the Natal *Tephrosia elongata* (Coll. by Wood, Mo. Bot. Gard.), the Hawaiian Islands *T. piscatoria* (Coll. by A. A. Heller), *Tephrosia pallens* (Bernhardi collection, Mo. Bot. Garden), *Tephrosia spicata* (Florida, Curtiss, No. 4823, Mo. Bot. Gard.), *Tephrosia Schiedeana*, Schl. (Fl. Mexico, San Blas, W. G. Wright, No. 1337), and *Tephrosia leucantha*, HBK. (Pringle, Pl. Mexicanae). In *T. leucantha* and *T. Schiedeana* these reservoirs also occur in the nutrient layer. Crystals were found in all the species except the last two.

Indigofera, L.

This genus has been studied by Nadelmann, who did some work on *I. tinctoria*, L. and *I. hirsuta*, L. The walls of the endosperm, in their early stages, are thin, and the cells are rich in plastic material. The young cells have what Nadelmann calls "Schleim-bläschen" imbedded in the protoplasm. The smaller mucilaginous masses unite to form a larger one. From these masses the wall is built up. The primary membrane in young seeds colors deep blue with sulphuric acid and iodine. The secondary membrane colors light blue. The tertiary membrane forms much later. It is noteworthy that the mucilaginous endosperm at no time showed transition starch. The endosperm exceeds the testa by five times its width in *I. tinctoria* and *I. hirsuta*. The white color of the seed, in cross-section, is due to the mucilaginous endosperm. The young flowers of *I. tinctoria* at the time of flowering contain indigo blue, known as indigotin.

Indigofera leptosepala, Nutt.

Pl. XIII. f. 1-1c.

Testa and endosperm vary in thickness from 83–866 μ. The cotyledons are 680 μ across, and uniform throughout.

Malpighian. Cells larger than the remainder of the testa, 30.8 μ long. Cuticle evenly developed; the wide light line below the cuticle colors light blue with chlor-iodide of zinc; the cuticularized layer takes the same color; the remainder of the cell-wall below, a darker blue. The cell-cavity is wide at the base but is abruptly contracted near the light line, and contains pigment, tannin, and protein grains.

Osteosclerid. Cells are small, wide in proportion to their length, thick-walled, and color blue with chlor-iodide of zinc.

Nutrient. This layer is much compressed. The cells are thin-walled, elongated, and contain an abundance of brown pigment and tannin.

Endosperm. The thick-walled, nearly isodiametric aleurone cells form a continuous layer; the walls are stratified; large pore-canals connect with adjoining cells; this layer is followed by the reserve cellulose. The walls are differentiated into three parts — primary, secondary, and tertiary. The stratified tertiary membrane colors blue with chlor-iodide of zinc, but not so deeply as the secondary stratified walls. The internal part of the endosperm consists of thick-walled, elongated cells with a small cavity. The cells of this part as well as of the middle portion contain protein.

Embryo. Cells of the first row, the epidermis, are smaller than those below, nearly isodiametric, with thick exterior walls. The interior cells are more loosely arranged. All of the cells contain fat and protein. The superior face of the cotyledon consists of several rows of palisade cells. Crystals of oxalate of lime are common in the interior cells.

Robinia, L.

Testa variously colored. Endosperm present. Nutrient layer compressed, containing pigment and tannin. The flowers and presumably the ovules contain a glucoside, robinin. The term has also been applied to the yellow coloring matter found in other parts of the tree.

Robinia Pseudacacia, L.

Pl. XIV. f. 1–1f.

This species has been studied by Nadelmann, Huss, and Holfert; its germination by Lubbock and others. Testa and endosperm uniformly developed, 249 μ thick. Cotyledons 796 μ in thickness.

Malpighian. Cells 95–98 μ long. Cuticle an even layer; cuticularized portion white; a narrow light line underneath the cuticularized layer; the cuticularized layer colors blue with chlor-iodide of zinc more rapidly than the light line, which takes on a much paler color than the rest of the cell-wall. Cell-cavity wide at the base, tapering upward. Chromatophores not observed. The cells contain pigment and some tannin.

Osteosclerid. Cells are thick-walled, elongated, less than half the length of the Malpighian cells. Chlor-iodide of zinc colors the walls blue and contents brown.

Nutrient. This layer is compressed and composed of three or occasionally more rows of elongated cells. An abundance of a yellowish-brown pigment is present in the cells; presumably this contains some robinin. The walls color blue with chlor-iodide of zinc.

Endosperm. The aleurone cells are thick-walled and contain fat and protein. Reserve cellulose consists of three or more layers of thick-walled cells with pore-canals. The cells contain protein. The internal part of the endosperm consists of thick-walled, elongated cells; cell-lumen reduced, containing but little fat and protein.

Embryo. Cells of the first row are smaller, with thick exterior walls; the cells below are larger and more loosely arranged; all of the cells contain fat and protein grains but no starch. Cell-walls color blue with chlor-iodide of zinc.

WISTARIA, Nutt.

Testa spotted with pigment, well developed. Nutrient layer well developed and differentiated into several distinct layers. Endosperm sparingly present.

WISTARIA SPECIOSA, Nutt. (*W. frutescens*, Poir. Gray's Manual, 6th ed. 134. *Kraunhia frutescens*, L., Greene.) *Pl. XIV. f. 2–2c.*

Testa strongly developed, 540–600 μ in thickness. Endosperm limited to one or two rows of cells. Nutrient layer with a great deal of pigment.

Malpighian. Cells quite uniform, 166 μ long. Cuticle irregular, followed by a narrow cuticularized layer, which refracts light strongly; the wide light line follows the cuticularized portion; the pore-canals extend beyond the line. When the cells are cut at right angles or obliquely the pores appear disconnected, with small projections; the projections between the pores color blue with chlor-iodide of zinc. The cell-cavity is wide at the base, tapering upward. Each cell usually contains a round chromatophore; occasionally it is elliptical or nearly square. With chlor-iodide of zinc the walls, light line, and cuticularized layer color blue. Some of the cells contain a brown or violet pigment. Tannin and some protein also occur.

Osteosclerid. Cells small when compared with the Malpighian, 20.4 μ long. The upper and lower bar nearly equal. Cell-cavity rather large and containing protein, some pigment, and tannin.

Nutrient. This layer is differentiated into two parts: (1) a narrow layer consisting of two to four rows of elongated cells containing some pigment, (2) three or four rows of much larger, thin-walled cells.

Mycotic. In this layer the cells are elongated, thick-walled, and somewhat irregular, comprising ten to fourteen rows; also some pigment.

Nucellus. Consists of one or two rows of thick-walled cells.

Endosperm. This consists of a narrow continuous layer of one or two rows of cells — the aleurone, whose walls are thickened. The cells contain protein grains.

Embryo. Cells of the first row smaller than those below, forming a continuous row; the exterior walls thickened; cells below are more loosely arranged, thinner-walled, a pore-canal present, and a triangular intercellular space at their angles. Palisade parenchyma wanting. The cells, except the first row, contain an abundance of large starch grains. Protein grains and fat in all of the cells.

ASTRAGALUS, Tourn.

A considerable number of species have been studied by Schleiden and Vogel, Huss, Nadelmann, Harz, Holfert, Strandmark, Mattirolo and Buscalioni, Chalon and others. The presence of endosperm has been noted by several observers, and in our American species, so far as I have studied them, it is present. It is present in the European *A. glycyphyllus*, *A. lamosus*, and *A. Onybrychis*. The testa is well developed. The osteosclerids are longitudinally striated in some species.

ASTRAGALUS MEXICANUS, A. DC.

Pl. XIII. f. 3–3b.

Testa and endosperm 130–145 μ thick. Cotyledons 664–830 μ across.

Malpighian. Cells 70 μ long. Cuticle forms an even layer; the narrow light line occurs under the light-colored cuticularized layer; several pores project into the walls below the light line; cell-cavity broad at the base, narrowing upward, constricted in several places. Cells carry a great deal of pigment, several chromatophores, and some protein grains.

Osteosclerid. Cells 14 μ long. Walls thickened and striated. Intercellular spaces large and elongated.

Nutrient. Cells of this layer much compressed, in three to six rows, thin-walled, containing a great deal of pigment and protein.

Endosperm. Variable as to quantity. The aleurone cells are thick-walled, forming a continuous row; the reserve cellulose is variable; the cells are thick-walled and on the addition of water are gelatinized; the internal layer of the endosperm consists of thick-walled, elongated cells. All of the cells contain protein.

Embryo. The cells of the first row are nearly isodiametric, continuous; exterior walls thickened. The cells below have thinner walls and are more loosely arranged. Fat and protein grains fill the cells, but starch is absent.

ASTRAGALUS CANADENSIS, L. (*A. carolinianus*, L.)

Pl. XIII. f. 5–5b.

Testa and endosperm 90–110 μ thick. The species agrees with *A. mexicanus* in having most of the yellow pigment in the Malpighian cells. The cells are 22 μ long, each containing one or more chromatophores. A small intercellular space occurs below the Malpighian cells. Longitudinal striae of the osteosclerids are not marked. Nutrient layer agrees with that of the last species. Endosperm is well-developed laterally. All of the cells of the endosperm contain protein. Embryo as in *A. mexicanus*. For complete reactions see Table A.

OXYTROPIS, DC. (*Spiesia*, Neck.)

Anatomically this genus is closely related to *Astragalus*. Endosperm is present in the species studied. One species was studied by Chalon.

OYTROPIS LAMBERTI, Pursh. (*S. Lamberti*, Pursh, Lamb.) *Pl. XIII. f. 4.*

Testa and endosperm 170–175 μ. This, the so-called loco weed, is said to cause disturbances in animals, but alkaloids have not been found in the seed or any other part of the plant.

Malpighian. Cells 40–42 μ long. Cuticle somewhat uneven; the narrow well-marked cuticularized layer colors blue with chlor-iodide of zinc; the light line occurs below the cuticularized layer, and this also colors blue; the remainder of the cell-wall takes on a darker blue color. Cells contain an abundance of pigment, tannin, and some plastic material.

Osteosclerid. Cell-walls thickened, not prominently I-shaped, but with an elongated intercellular space.

Nutrient. Layer consists of thin-walled elongated cells, from ten to twelve rows. Pigment more abundant in lower than in upper part. Walls color blue with chlor-iodide of zinc.

Endosperm. The aleurone layer consists of thick-walled cells; the underlying thick-walled cells of the reserve cellulose become mucilaginous on the addition of water. The internal part consists of thick-walled, elongated cells. The cells contain protein.

Embryo. Cells of the first row smaller, with thick exterior walls; cells below not so compact and with thinner walls.

Cell-walls color blue with chlor-iodide of zinc. Starch is absent but cells contain fat and protein.

OXYTROPIS DEFLEXA, DC.

Pl. XIII. f. 2.

Malpighian cells do not differ essentially from those of *O. Lamberti*. The walls of the osteosclerids are thick; the nutrient layer is much compressed and thin-walled. Aleurone layer prominent, followed by the thick-walled mucilaginous endosperm, and the narrow, elongated, thick-walled internal layer. Embryo as in last species.

GLYCYRRHIZA, Tourn.

Schleiden and Vogel, and Chalon, studied the genus with reference to the presence of endosperm; the mucilaginous character of this by Nadelmann. Brandis has also studied the genus. *G. echinata* is without starch but contains an abundance of fat and protein. Endosperm is more abundant in *G. lepidota* than in *G. echinata*.

GLYCYRRHIZA LEPIDOTA, Pursh.

Pl. XV. f. 6.

Testa and endosperm 490–500 μ thick. Endosperm variable in different parts of the seed, but usually well developed.

Malpighian. Cells 70–75μ long. Cuticle somewhat irregular; the light-colored cuticularized layer is followed by a narrow but sharply marked zone, the light line; cell-cavity is large at the base, gradually tapering upward. Pore-canals extend into wall beyond the light line. Cells contain pigment and some plastic material.

Osteosclerid. The I-shaped cells are thick-walled, with small projections somewhat similar to those shown for *Ervum Lens* by Mattirolo and Buscalioni. The intercellular space is elongated. The cells attain their greatest development in the hilar region. All of the cells carry some pigment and plastic material.

Nutrient. This layer is much compressed and thin-walled; cells number from four to six rows. Pigment is most abundant in the lower part of the layer.

Endosperm. Aleurone layer consists of nearly isodiametric thick-walled cells. The mucilaginous reserve cellulose is variable in quantity. Cell-walls differentiated into primary, secondary, and tertiary. Pore-canals large. Internal part of the endosperm consists of thick-walled, elongated cells. All of the cells contain protein grains.

Embryo. Cells of the outer row smaller than those within; exterior walls thickened, those below more loosely arranged than the epidermal; more compact and with thicker walls than those of *Astragalus mexicanus.* Cells contain fat and protein grains but no starch.

PAPILIONACEAE — Hedysareae.

AESCHYNOMENE, L.

Endosperm has been found in several species of *Aeschynomene. A. Selleri, A. falcata,* and *A. fluminensis* were studied by Schleiden and Vogel. *A. paludosa* was studied by Payen with reference to the nature of cellulose. Lubbock, who studied the germination of *Hedysarum coronarium,* which belongs to the same group, states that endosperm is absent from this species. He also studied *Aeschynomene aspera* but says nothing about the endosperm. Marloth studied *Hedysarum* with reference to its protection. The *Hedysareae* appear to vary in regard to the presence of starch. *Ornithopus sativus* is without starch, while *Onobrychis sativa* has an abundance of round starch grains. Harz gives a key for some of the European genera, based on the abundance of starch. *Hedysarum flexuosum, H. fruticosum* and *Coronilla varia* have an abundance of starch. In *H. capitatum, Coronilla glauca,* and *C. coronata,* starch grains are not abundant. Iodine does not always color the starch. In the second group, the starch is colored only on the addition of potassium hydrate. *C. scorpioides* is without starch.

AESCHYNOMENE HISPIDA, Willd. (*A. virginica,* L., BSP.) *Pl. XV. f. 4.*

Testa and endosperm 318.8 μ thick. Endosperm somewhat variable.

Malpighian. Cells 80–82 μ long. Cuticle uniformly developed, the narrow cuticularized layer followed by the well-developed light line; cell-cavity gradually tapering from the base; pores extend much beyond the light line. Cells contain plastic material.

Osteosclerid. Cells I-shaped, with uniform, elongated, intercellular spaces. The walls are thickened and the cells contain some plastic material.

Nutrient. This layer is much compressed, consisting of three to six rows of cells containing pigment.

Endosperm. Variable in thickness. Aleurone layer well developed with thick-walled cells. Cells of the reserve cellulose are thick-walled with large pore-canals. The walls are differentiated into three parts as in *Glycyrrhiza* and many other genera. The internal part of the endosperm consists of thick-walled, elongated cells with a small cell-cavity. All of the cells contain fat and protein grains.

CORONILLA, Tourn.

The genus *Coronilla* has been studied by Chalon, who found endosperm uniformly present in a large number of species examined by him. *C. montana* was studied by Nadelmann, who found a small amount of mucilaginous endosperm present, as well as starch in the cotyledons. Harz noted the occurrence of starch in the cotyledons of this species. The same species is described in detail by Mattirolo and Buscalioni. Lubbock studied the germination of *C. juncea* but does not describe the seed. Parts of the plant are said to be poisonous, although it is used for forage.

CORONILLA MONTANA, Scop.

Pl. XXII. f. 2. Pl. XXIII. f. 3.

I was unable to obtain good seed of *C. varia* and therefore substituted *C. montana.* Testa and endosperm 125–230 μ thick. Testa below the Malpighian cells usually 50 μ thick.

Malpighian. Cells 40–49 μ long, thick-walled and deep brown; light line removed some distance from the cuticle. When sections are treated with ferric chloride the walls and contents give the reaction for tannin.

Osteosclerid. Cells are rather short, thick-walled, and with somewhat elongated intercellular spaces. With sulphuric acid and iodine the walls give the reaction for cellulose.

Nutrient. This layer is much compressed, differentiated into two parts; cells of the lower part are thicker-walled, with lumen much reduced. The cells contain tannin and pigment.

Endosperm. Variable in amount. The aleurone layer consists of thick-walled cells containing protein; the cells below are mucilaginous, and thick-walled; the internal part of the endosperm consists of thick-walled elongated cells. The reserve cellulose cells contain some protein.

Embryo. The first row of cells smaller than those below, the interior cells more loosely arranged; palisade cells of the inner face of the cotyledons comprise two rows. All of the cells contain fat and protein but no starch. — (Curling-Joad Herb., Mo. Bot. Gard.)

HEDYSARUM, Tourn.

Endosperm is but slightly developed, as Nadelmann indicates for *H. sibiricum.* The same species was studied by Strandmark. Schleiden and Vogel have given an account of *H. obscurum.* Chalon studied seven species with reference to the presence or absence of endosperm. In the species studied by myself it is not well developed.

HEDYSARUM BOREALE, Nutt.

Pl. XV. f. 7.

Testa and endosperm 95–100 μ in thickness. Endosperm and nutrient layers vary somewhat.

Malpighian. Cells 52–55 μ long. Cuticle somewhat uneven, and below it the narrow, sharply defined, cuticularized layer with its conical projections; the well marked but narrow light line is below the cuticularized layer; the cell-cavity is wide at the base, gradually tapering upward; each cell contains one large and occasionally several smaller chromatophores.

Osteosclerid. Cells thick-walled, I-shaped, with an elongated intercellular space. Chlor-iodide of zinc colors the walls less intensely than the Malpighian cells.

Nutrient. The layer is compressed; the cells are thin-walled, elongated, and contain pigment and protein. Walls color pale blue with chlor-iodide of zinc.

Endosperm. Aleurone cells thick-walled with the pore-canals slightly irregular. The cells are larger than in *Aeschynomene* or *Astragalus.* In most parts of the seed the aleurone is the extent of the endosperm; laterally, however, more endosperm occurs, and here it is mucilaginous. Walls color blue with chlor-iodide of zinc. Cells contain fat and protein.

Embryo. The cells of the first row smaller and nearly isodiametric, the exterior walls thickened; cells below larger, longer than wide. The walls color blue with chlor-iodide of zinc. The cells contain an abundance of fat and protein. On the addition of iodine a few elliptical or spherical starch grains may be seen. On the addition of chlor-iodide of zinc a great many more grains are colored. — (Wyoming, Nelson, Mo. Bot. Gard.)

DESMODIUM, Desv. (*Meibomia*, Adans.)

Malpighian cells carry pigment in variable amounts. Osteosclerids are of the characteristic I-shape. Chalon studied several species with reference to endosperm, finding it present in *D. floribundum*, G. Don., *D. canadense*, DC., *D. gyrans*, DC., *D. incanum*, DC., *D. latifolium*, DC., *D. gangeticum*, DC., *D. uncinatum*, DC., *D. triquetrum*, DC., and *D. umbellatum*, DC. All of the species which I have examined contain endosperm, *e. g.*, *D. nudiflorum*, DC., *D. canescens*, DC., *D. strictum*, DC., and *D. Dillenii*, Darl. Lubbock studied the germination of *D. canadense*, but does not describe the seed.

DESMODIUM CANESCENS, DC. (*M. canescens*, L., Kuntze.) *Pl. XV. f. 3a.*

Testa and endosperm 140–150 μ thick. The testa is uniform but the endosperm is variable.

Malpighian. Cells 50–52 μ in length. Cuticle uneven; cuticularized layer narrow; light line runs close under the cuticularized layer; several pore-canals extend into the wall below the light line, which connect in part with the cell-cavity. The cell-cavity is large at the base but narrows rather abruptly, and in upper part occurs as a narrow cavity to the light line, where it widens again. Sections which had passed through potassium hydrate before mounting in glycerine, after the lapse of several years colored uniformly dark brown.

Osteosclerid. Cells I-shaped, with elongated intercellular spaces, and thickened walls. Cells contain tannin and pigment. Sections treated with potassium hydrate change from a yellowish to a dark brown color.

Nutrient. Layer compressed, consisting of from four to six rows of cells which are elongated and thick-walled. Contain but a small amount of pigment and some protein grains.

Endosperm. Cells of the aleurone layer continuous, nearly isodiametric, thick-walled, containing protein grains and fat; the walls of the reserve cellulose differentiated into three parts, primary, secondary, and tertiary; internal layer of endosperm is made up of thick-walled, elongated cells. The cells of the reserve cellulose layer contain protein and fat.

Embryo. Cells of the first row nearly isodiametric; the exterior walls of the epidermis are thickened; cells below more loosely arranged with intercellular spaces. Inner face of the cotyledons with isodiametric epidermal cells, and several rows of palisade cells, the outer row much larger. Procambial bundles more than ten. All of the walls of the cotyledons color blue with chlor-iodide of zinc. Cells contain protein and fat but no starch. — (Sapulpa, Indian Terr., Bush, Mo. Bot. Gard. — East St. Louis, Ills., Pammel.)

DESMODIUM STRICTUM, DC. (*M. stricta*, Pursh, Kuntze.) *Pl. XV. f. 2.*

Testa and endosperm 90–100 μ thick. Malpighain cells 50 μ long; light line below the cuticularized layer, but further removed than in the last species; the yellow pigment is abundant in freshly mounted specimens. Nutrient layer compressed; the cells are elongated and contain an abundance of pigment. Aleurone layer as in *D. canescens.* Walls of the reserve cellulose cells greatly thickened, in some cases very irregular; the cell-cavity small. Internal layer of endosperm consists of elongated, thick-walled cells. Embryo as in last species.

DESMODIUM NUDIFLORUM, DC. (*M. nudiflora*, L., Kuntze.) *Pl. XXIII. f. 2.*

Testa and endosperm 90–100 μ thick. Malpighian cells 42 μ long; cuticle even; light line under the cuticularized layer. Pigment mostly in the lower part of the cell-cavity. Osteosclerids 12 μ long, I-shaped, thick-walled, with elongated intercellular spaces. Nutrient layer compressed, composed of somewhat elongated cells. Endosperm not strongly developed; the aleurone layer continuous, followed by several rows of thick-walled cells.

LESPEDEZA, Michx.

The testa in this genus is usually yellowish. In structure it is much like that of *Desmodium* but in some of the species endosperm is more abundant than in *Desmodium*. Schleiden and Vogel recorded endosperm for the genus, and stated that it is differentiated into three parts. Chalon also indicated its presence in several species of the genus. Lubbock studied the germination of *L. angustifolia*, Ell., but the seed is not described. Protein and fat occur in all of the cells of the embryo. Starch is absent.

LESPEDEZA VIOLACEA, Pers.

Malpighian. Cells 50 μ long; cuticle an even layer which colors brown with iodine; the cuticularized layer is light colored and prominent, it colors blue rapidly with chlor-iodide of zinc. The light line occurs below the cuticle, with numerous pores extending into the wall below. Cell-cavity somewhat irregular, large at the base, with a single chromatophore; in addition, the cells contain a yellowish pigment and tannin.

Osteosclerid. Cells 16–28 μ long, thick-walled and slightly constricted in the middle; cell-cavity larger in the lower part of the cell; the intercellular space is elongated. Walls color blue with chlor-iodide of zinc.

Nutrient. This layer is compressed. Cells thin-walled and elongated. Some of the larger measure 11.2×56 μ. Cells of the inner part longer than broad, thin-walled, containing a great deal of yellowish-green pigment. The walls color blue with chlor-iodide of zinc.

Endosperm. The aleurone layer continuous, consisting of small, thick-walled, nearly isodiametric cells; the contents color red very rapidly with fuchsine, making a strong contrast with the nutrient layer and the rest of the endosperm. The cells of the mucilaginous reserve cellulose are thick-walled, with a small cavity. The middle lamella stains blue with chlor-iodide of zinc when it is allowed to act for some time. The mucilaginous walls color faintly at first. The internal part of the endosperm consists of thick-walled elongated cells.

Embryo. Epidermal cells nearly isodiametric; exterior walls thickened; the cells below are elongated and more loosely arranged, with small intercellular spaces; two rows of palisade cells occur on upper face, a third is interrupted and connects with the procambial vessels. The cells contain protein and fat but no starch. Walls color blue with chlor-iodide of zinc. — (Sapulpa, Indian Terr., Bush, No. 1846, Mo. Bot. Gard. — St. Louis, Mo., Pammel.)

LESPEDEZA RETICULATA, Pers. (*L. frutescens*, L., Britton.)

Testa and endosperm 108–116 μ thick. Malpighian cells well developed; endosperm somewhat variable, reaching its greatest development on the sides.

Malpighian. Cells 56 μ long. Cuticle somewhat uneven; cuticularized layer narrow, followed by a narrow but well marked light line; a second less sharply defined zone occurs in the lower part of the Malpighian cells. Several pores extend into the wall below the upper light line. Cells contain a large chromatophore somewhat variable as to position. Yellowish pigment and tannin abundant, also smaller granules of plastic material.

Osteosclerid. Cells thick-walled, 14 μ long, containing protein grains, some pigment and tannin. The intercellular spaces are elongated.

Nutrient. This layer is much compressed, the cells are thin-walled, elongated, and contain a great deal of pigment and tannin.

Endosperm. Aleurone cells longer than broad. The reserve cellulose below is not well developed; all of the cells contain fat and protein.

Embryo. Cells of the first row smaller than those below, having thick exterior walls; the lateral walls are thinner. Cells below not so compactly arranged as the epidermal. All of the cells contain fat and protein but no starch.

LESPEDEZA STUVEI, Nutt.

Pl. XV. f. 3b. Pl. XVI. f. 5.

Testa and endosperm 116–132 μ thick. Light line occurs close under the cuticle. Malpighian and osteosclerid cells contain an abundance of pigment and tannin; the latter are greatly elongated in the hilar region. Endosperm more strongly developed than in *L. reticulata*. The reserve cellulose gelatinizes readily on the addition of water. The internal layer consists of thick-walled elongated cells with a narrow lumen. Cells of embryo as in other species. Contains fat and protein but no starch.

LESPEDEZA CAPITATA, Michx.

Pl. XVI. f. 4.

Testa and endosperm 90–100 μ thick. Light line occurs close under the cuticle. A large spherical chromatophore occurs in the pigmented Malpighian cells, which is variable as to its position in the cell. The long pores extend to the middle of the cell. The osteosclerids are short. The nutrient layer is compressed, containing much pigment. Endosperm as in *L. Stuvei;* the aleurone cells are thick-walled, and the reserve cellulose is mucilaginous. Embryo as in the other species, containing fat and protein but no starch.

STYLOSANTHES, Sw.

Schleiden and Vogel were unable to determine whether endosperm occurred in the genus. It is present though much reduced.

STYLOSANTHES ELATIOR, Swartz. (*S. biflora*, L., BSP.)

Pl. XXII. f. 1–1c.

Thin testa and endosperm 50–65 μ thick.

Malpighian. Cells 14 μ long, and 8–9 μ in width. Cuticle thin and even; a narrow cuticularized layer under the cuticle, and below it the narrow light line; cells with a rather large cell-cavity and containing considerable tannin. Pore-canals numerous and very plainly marked when treated with chloral hydrate. In surface view they appear as short canals much as in *Arachis*. Specimens treated with potassium hydrate and then mounted in glycerine are colored reddish. The whole Malpighian layer on the addition of iodine colors brown except the light line which remains as a translucent zone. Ferric chloride, when allowed to act for some time, colors the walls and contents bluish-black, in strong contrast with the cells below.

Osteosclerid. Cells 10–14 μ long, thick-walled. Intercellular spaces elongated; frequently the cells are very widely separated. Cells contain protein grains. Walls are not greatly thickened, not nearly as much as in *Lespedeza*.

Nutrient. This layer is much compressed, reaching its greatest development in the hilar region. The cells are elongated and thin-walled. Contain pigment and a little tannin. Lignified only where the vascular elements occur.

Endosperm. This consists mainly of one layer of cells, the aleurone, but an internal layer, made up of elongated thick-walled cells, may be made out in some parts of the seed.

Embryo. The epidermal cells are smaller than those below; exterior walls thickened. Palisade cells on the interior face of the cotyledon arranged rather compactly. All of the cells contain protein and a great deal of fat, also simple and compound crystals of calcium oxalate, one or occasionally several in nearly every cell. — (Sapulpa, Indian Terr., B. F. Bush, No. 111.)

Arachis, L.

Several accounts have been given of the testa of the peanut. The earliest account of the genus is by Chalon, who gave the essential facts with reference to its structure. Schleiden and Vogel gave an account of the cotyledons. Later Harz, and Mattirolo and Buscalioni, gave an account of the structure of the seeds. Pfaefflin, who studied more especially the tracheid island, also describes other parts of the testa. Godfrin discusses the comparative anatomy of the cotyledons. In many respects the genus closely resembles *Stylosanthes*. The protective features are replaced by the pod in both genera. Marloth has discussed these features for the peanut. The Malpighian cells are short, and the light line is indistinct or wanting. The osteosclerid layer is suppressed. The related *Zornia bracteata*, J. F. Gmel. has well-developed Malpighian cells and an osteosclerid layer. The testa in both genera is prominently veined. The seeds are very oily, but those of *Arachis* more so than those of *Stylosanthes*. Endosperm much reduced. Many chemical analyses have been made. These may be found in König, Harz, and Jenkins and Winton.

ARACHIS HYPOGAEA, L.

Pl. XXII. f. 3–3g.

Testa 112 μ thick. The endosperm occurs as a single row, the aleurone. The outer part of the testa brown, the inner yellow. It is differentiated into three parts; the nutrient layer is, however, divided.

Malpighian. Cells short, nearly as broad as long, measuring 16×20 μ. Cuticle delicate. Numerous thickened processes from the cuticularized layer, with small pore-canals; surface view similar to that of *Stylosanthes;* light line is indistinct in the upper part of the cell. Cavity wide at the base, narrow in the upper end. Cells contain but a small amount of pigment; the walls are colorless, but color blue rapidly with chlor-iodide of zinc. Cells contain a small amount of tannin.

Osteosclerid. This layer is suppressed.

Nutrient. Cells thin-walled and elongated, containing a reddish and a yellow pigment. The cells above are larger. The lignified vascular elements occur in the nutrient layer above the mycotic. A second part of the nutrient layer below the mycotic is thick-walled and compressed, containing a yellow pigment and an abundance of tannin.

Mycotic. This layer is compressed. The cells are thin-walled and elongated, star-shaped, colorless, and without pigment.

Endosperm. This layer is reduced to a single row of thick-walled cells, the aleurone, containing protein.

Embryo. Cells of the outer row with the exterior walls thickened, much smaller than those below; the cells of the internal part of the cotyledon like those of the outer part and followed by cells which are elongated at right angles, gradually becoming larger, with small intercellular spaces. The walls of all the cells below the epidermal layer are provided with pores. The epidermal cells of the caulicle are much larger, but smaller than those below. All of the walls color blue with chlor-iodide of zinc. Starch colors blue with iodine. The cells have comparatively few round or elliptical starch grains, with an elongated rift, which are soluble in weak hydrochloric acid. Alcannin colors the oil plasma red in the course of a few seconds. The aleurone, which is imbedded in the oil plasma, is very abundant. When mounted in glycerine beautiful aleurone grains with crystalloid and globoid come out. As a rule there is but a single crystalloid in the grain, each showing one globoid; the latter does not, however, always show.

Chapmannia, Torr. & Gray.

The testa is prominently veined, delicate, whitish and, with endosperm, 33 μ thick, except in hilar region, where it measures 140 μ. The endosperm is but sparingly developed, consisting of a single row of cells, the aleurone layer.

Chapmannia is undoubtedly closely related to *Arachis* and *Stylosanthes*. It is the only genus studied, from which the Malpighian cells are absent. The epidermal cells are thin-walled; the light line is absent. The osteosclerid layer is present and consists of elongated cells with intercellular spaces, or it is but little differentiated.

Chapmannia floridana, Torr. & Gray.

Pl. XVII. f. 5.

The epidermal cells are usually isodiametric, the exterior walls but slightly thickened; the lateral walls are thin. No pore-canals from the surface as in *Arachis;* the large cell-cavity contains a nucleus.

Osteosclerid. The cells are thin-walled, larger than the epidermal cells, and occur only in the hilar region; intercellular spaces vary in size.

Nutrient. In most parts of the seed this layer follows the epidermis; it is much compressed, the cells are thin-walled and elongated. Vascular elements abundant in this layer. The thick-walled pigment layer and the mycotic are absent.

Endosperm. A single row of thick-walled cells, the aleurone, occurs especially in the hilar region. Cells contain protein.

Embryo. The epidermal cells below the endosperm are mostly isodiametric followed by more loosely arranged cells with thinner walls; the internal part of the cotyledons, with an epidermis similar to that of the outer part, having several rows of palisade cells. Cells contain an abundance of fat and protein.— (Fla., A. S. Hitchcock, Mo. Bot. Gard.)

ZORNIA, J. F. Gmel.

The testa of this genus is very different from that of *Arachis*, *Stylosanthes*, and *Chapmannia*. Even before making a section, the hardness of the testa is evident. The genus is allied to *Desmodium* and *Lespedeza* rather than to the other members of the subtribe.

ZORNIA BRACTEATA, J. F. Gmel.

Malpighian. Cells nearly half as long as the remainder of the testa, thick-walled. Cuticle evident; cells with longitudinal pore-canals; cuticularized layer inconspicuous; light line near the cuticularized layer. Cells carry some pigment.

Osteosclerid. Cells I-shaped, with large intercellular spaces; they contain a great deal of pigment.

Nutrient. Layer compressed, consisting of four or five rows of pigmented cells.

Endosperm. Reduced to a single row of cells, the aleurone.

Embyro. Epidermal cells smaller than the parenchyma cells below, isodiametric; the palisade cells smaller than the underlying parenchyma, narrow and in two to three rows. The procambial bundles are small. Reserve material consists of fat and protein. Starch is absent.

PAPILIONACEAE — Vicieae.

VICIA, Tourn.

Various species of the genus have been studied by Godfrin, Schleiden and Vogel, Beck, Harz, Mattirolo and Buscalioni, Nadelmann, Chalon, Macchiatti, Tschirch, Oesterle, Russow, Pringsheim, Monnier, Sempolowski, Dahmen, Holfert, Bischoff, Harberlandt, Sachs, and Huss.

Schleiden and Vogel, as well as Chalon, considered the seeds of the genus exalbuminous. Bischoff recorded endosperm for the genus as early as 1833, and Beck much later indicated its presence in some species, but Nadelmann was unable to find endosperm in the genus. In the species which I have studied endosperm was present, though often reduced to the aleurone cells accompanied by thick-walled, elongated cells — the internal layer. Beck figures and describes endosperm for *Vicia Faba*, and Macchiatti, for *V. narbonensis*. The testa of the genus is variously pigmented — brown, yellow, or sometimes almost black. Malpighian cells elongated and large. Beck records silica in the Malpighian cells of *V. Faba*. I have not been able to confirm this. Chromatophores present. Osteosclerids elongated, thick-walled, and I-shaped.

The following brief characters of species not studied by me are taken from Harz. The Malpighian cells of *Vicia narbonensis*, L. are 180–183 μ long, colored dark brown. Osteosclerids short. The nutrient layer is divided into three parts. Endosperm absent according to Harz. Palisade cells of the embryo absent. Large intercellular spaces in the cotyledons, and an abundance of starch. *Vicia lathyroides*, L. has shorter Malpighian cells which are somewhat variable in size owing to the presence of small depressions between the ridges. The depressions are 45 μ long and the projections are 75–80 μ long. Cotyledons with large starch grains. *V. hybrida*, L. has long, dark brown Malpighian cells. Endosperm absent. Starch in the cotyledons not as abundant as in the last species. The Malpighian cells of *V. lutea*, L. are 110–115 μ long. The upper part of the cell is colorless, the lower brown. Endosperm reduced or absent. Cotyledons with an abundance of starch grains. The Malpighian cells of *Vicia sepium*, L., in the dark-colored varieties, contain a great deal of pigment and tannin. Starch grains 14–26 μ in diameter. In *V. Michauxii*, Spr., Malphigian cells 56.8 μ long, upper part colorless. Osteosclerids 10–12 μ long. Cells of cotyledons somewhat elongated, containing oval, spherical, or ovate starch grains, 11–18 μ in diameter. The seeds of several species are of economic importance as food.

VICIA SATIVA, L.

Pl. XVI. f. 1–2.

This species has been studied by Harz, Tschirch and Oesterle, Beck, and Sempolowski. Testa irregular, with small projections, 126 μ thick. Endosperm reduced to a single layer. The presence of endosperm has been indicated by the above writers. Beck speaks of an aleurone spot (Aleuronefleck) in the epidermal cells of the cotyledons of this and other species of the genus *Vicia.*

Malpighian. Cells 72–75 μ long, pointed at the upper end; cuticle very irregular because of the projections; cuticularized layer most prominent in the depressions; pores project into the walls below the light line, and partly connect with the cell-cavity; the upper part of the cell is not pigmented, or very little. The light line occurs just above the pigmented part of the cell. Cell-cavity is large at the base, narrows upward, becoming much constricted below the light line, and above widens again. Small lateral projections or pores extend into the wall at right angles to the cavity. A large chromatophore, some pigment, and small granules occur in the cavity. The walls in lower part of cell are colored bluish-brown.

Osteosclerid. Cells are thick-walled, 13–16.8 μ long, longitudinally striated. Upper and lower cross-bars nearly equal; the intercellular spaces elongated. Tschirch and Oesterle state that this layer is not very strongly developed, but in specimens which I have examined it is well developed. These cells are more or less variable, as indicated by Harz, who states that they are from 11–13 μ long.

Nutrient. This layer is differentiated into two parts; the upper consists of thin-walled, elongated cells with a yellowish pigment; the cells of the lower part are larger, thin-walled and elongated, containing a brown pigment.

Nucellus. This consists of a narrow zone of compressed cells.

Endosperm. Occurs in the form of thick-walled elongated cells with a narrow cell-cavity. Usually only one or two rows of cells.

Embryo. The outer row of cells of the cotyledon is continuous. The exterior walls are thickened; cells below are more loosely arranged; small intercellular spaces in the angles of the cells; the epidermal cells contain fat and protein, the others in addition an abundance of spherical or elliptical starch grains measuring $25 \times 22.5\,\mu$–$50 \times 25\,\mu$. Palisade cells wanting.

VICIA FABA, L.

Pl. XVI. f. 6. Pl. XXVI. f. 2–2j.

The earliest study of this species dates back to Bischoff, who indicated its general structure and noted the presence of endosperm. A more detailed account was given by Sempolowski, followed by Beck. Both writers note the presence of endosperm, although these writers both erred with reference to endosperm, since they considered the inner part of the testa to be endosperm. Chalon, as well as Schleiden and Vogel, stated that it is exalbuminous. I fully agree with Harz that endosperm is absent or sparingly developed. Tschirch and Oesterle refer to the layer of cells which follows the inner part of the testa in *Phaseolus multiflorus* as perisperm. This layer in *Vicia Faba* agrees with that of the scarlet runner, but it is difficult to say except from developmental studies whether this is to be regarded as perisperm or endosperm. Pringsheim and Nobbe also studied the species; and Holfert, with reference to the nutrient layer. Germination of the seeds was studied by Sachs, Marek and others. Dahmen studied the funiculus, and Le Monnier the nervation. Comparative studies were made by Harz, Tschirch and Oesterle, and Mattirolo and Buscalioni.

Economically the seed is of considerable importance. Many chemical analyses have been made; these are compiled by König, Jenkins and Winton, and Harz. The latter also records specific weight and other physical properties.

Malpighian. The cells are 185–200 μ long. Harz gives the length as 135–185 μ. This varies somewhat in different varieties. The form studied was sold under the name of broad bean — a large-seeded cultivated garden variety. Cuticle slightly irregular; light line below the cuticularized layer; cell-cavity irregular, constricted at several places, conspicuously enlarged below the middle, then usually tapering upward. Lateral canals project into the walls as in *V. sativa.* Beck mentions the occurrence of a silicified body in the cell-cavity, but I have been unable to make this out. One or more conspicuous chromatophores occur in the cell-cavity. In addition to the lateral pores, long longitudinal canals extend from the surface. These in some cases connect with the cell-cavity below the light line or at the constricted partition. The cells are colored brown, especially the lower part. With chlor-iodide of zinc the cuticularized layer and a broad clear band below, the light line, color blue rapidly.

Osteosclerid. The osteosclerids vary in length from 70–140 μ. Harz gives their length at 58–68 μ, becoming larger in the hilar region; here assume considerable importance, comprising more than one row of cells. The walls are greatly thickened and frequently have lateral processes. In part these cells are joined to the thick-walled parenchyma. In parts of the seed away from the hilum and raphe the cells are prominently marked with longitudinal canals.

Nutrient. This layer is differentiated into two or three parts; the cells are thin-walled, but in the lower part of the layer thicker-walled. Contents stain deeply with fuchsine. The lower portion contains an abundance of pigment, deposited in two forms, one in large scattered elliptical or spherical masses darker in color than the pigment of the remaining cells. The vascular elements are contained in the nutrient layer.

Endosperm. The endosperm consists in the main of somewhat elongated cells with mucilaginous walls; the contents consist of protein.

Embryo. The exterior walls of the epidermis thick; the walls of underlying cells less thickened; towards the interior the cells become larger; the internal face of the cotyledons without palisade parenchyma, but the underlying cells much larger than the epidermal. Procambial elements are well developed, with well formed spiral ducts. Cells of the cotyledons contain an abundance of starch and protein but little fat.

VICIA AMERICANA, Muhl.

Pl. XXVI. f. 1–1c.

Testa and endosperm greenish-brown, somewhat glossy, 160–175 μ thick; Malpighian cells 55 μ long, irregular with conical points; cuticle thick, upper part colored brownish; light line a distinct zone below the brown portion. When treated with fuchsine the light line stands out as a nearly colorless zone. With chlor-iodide of zinc the walls color bluish-black except the light line, which takes on a lighter blue color. The cell-cavity is wide at the base but becomes narrow below the light line. Several conspicuous pores extend into the walls from the cuticularized layer. Cells contain tannin and chromatophores. The osteosclerids are 20–30 μ long, I-shaped. Prominent longitudinal pore-canals occur in the hilar region; in this region more than one layer of cells occur. Cells contain much tannin. Nutrient layer green; pigment occurs in masses or apparently as distinct grains. The lower part of this layer is without pigment. Nutrient layer is followed by what appears to be the nucellus. A single layer of cells next to the embryo is certainly endosperm. The cotyledons have a yellow color but when mounted in water lose this color. The cells of the first row in the cotyledons are nearly isodiametric, followed by larger cells, with intercellular spaces, having pore-canals in the walls. Palisade cells absent. Cells of cotyledons contain an abundance of starch and protein and some fat. — (Pullman, Washington, Lake and Hall, Mo. Bot. Gard.)

LATHYRUS, Tourn.

Many of the species carry a brown pigment with a well-developed testa. Endosperm much reduced or wanting. Schleiden and Vogel record its occurrence for *L. tingitanus* and its absence from *L. tuberosus*. Chalon records it as absent from the genus. His conclusions were based on the study of eight species, including those studied by Schleiden and Vogel.

In *L. venosus* and *L. maritimus* the endosperm consists of but a single layer of cells. Harz indicates the presence of some endosperm in parts of the seed of *L. sativus*. Starch is abundant in all of the species. Huss studied *L. Cicer*, *L. pratensis* and *L. sylvestris* with reference to the taking up water by the cotyledons. Holfert studied the nutrient layer of *L. sylvestris*. Good accounts of *L. sativus*, L. are given by Tschirch and Oesterle, and Mattirolo and Buscalioni. Strandmark gives a short account of *L. latifolius*. Analyses of the chemical products of *L. sativus* are given by König and Harz.

LATHYRUS VENOSUS, Muhl.

Pl. XVI. f. 6b. Pl. XXXIV. f. 1. Pl. XXXV. f. 3.

Testa 130–150 μ thick; endosperm much reduced.

Malpighian. Cells 58–70 μ long. Cuticle somewhat uneven. Cuticularized layer well developed; the light line occurs just below the latter; pores project into the walls below. The walls are striated. Cell-cavity wide at the base, and gradually tapering upward, then becoming constricted. Lateral pores evident. Tschirch and Oesterle have called attention to these in *L. sativus*. A single chromatophore is present in the upper part of the cell-cavity; numerous small grains in the lower part. Cells are pigmented.

Osteosclerid. Length of cells varies from 19–50 μ; intercellular spaces elongated. I-shaped cells with upper and lower bars nearly equal; cells thick-walled, elongated and striated; they contain tannin and protein.

Nutrient. This layer is much compressed. The cells are elongated, thin-walled, with small intercellular spaces. Cells contain an abundance of pigment and tannin.

Nucellus. This layer is compressed and reduced.

Endosperm. Layer is much reduced. Consists of a single layer of thick-walled elongated cells, having a narrow cell-lumen in which small protein grains occur.

Embryo. Cells of the outer row small, having greatly thickened exterior walls; occasionally with some brown pigment. The cells below are thinner walled and more loosely arranged, with intercellular spaces. These cells contain some pigment, protein, and a great deal of starch. The starch grains are rather small. The outer or epidermal layer only, contains protein.

LATHYRUS MARITIMUS, Bigelow.

Pl. XVI. f. 3.

Testa 200–215 μ thick, as in *L. venosus.* Malpighian cells 61–70 μ long and pigmented; cell-cavity large at the base with a more regular outline and less conspicuous lateral pore-canals. Several chromatophores occur in Malpighian cell. The pigmented osteosclerids are thick-walled, 40–60 μ long, marked with longitudinal striae. Nutrient layer differentiated into two parts. Lower part contains more pigment than the upper. Endosperm as in last species. Cells of the embryo contain some pigment and protein grains. Starch grains abundant, 33×14 μ–42×28 μ.

The Malpighian cells of *Lathyrus latifolius*, L., *L. odoratus*, L., *L. sylvestris*, L., and *L. sativus*, L. are irregular on the surface. The light line occurs in the upper third of the cell. In all of these species the cell-cavities contain protein and chromatophores. The Malpighian cells of *L. odoratus* are 110–125 μ long. The testa is 185–200 μ thick. The testa of *L. latifolius* is 95-100 μ thick and the Malpighian cells are 40–45 μ long. In *L. sylvestris* the testa is 180–185 μ thick and the Malpighian cells are 67–80 μ long. The osteosclerids in all of these species are I-shaped, with prominent longitudinal canals. In *L. latifolius* these are 26–30 μ long; in *L. odoratus* about the same; in *L. sylvestris* 22–50 μ long. The nutrient layer in these species does not differ essentially from that of *L. maritimus.* Endosperm is but sparingly developed. In *L. sativus* the aleurone cells are elongated and narrow. Starch grains in the cells of the embryo are spherical or elliptical, variable. The starch grains are large in *L. odoratus.* Compound grains occur occasionally in *L. sativus.* Cell walls are provided with pore-canals.

The starch grains of the different species vary in size as follows: *L. latifolius* 14×19.6–16.8×22–7.4×19.6 μ. *L. odoratus* 16.8×28–11.2×31–16.8×36 μ. *L. sylvestris* 14×26.8–16.8×22.4–8×25. Palisade cells are wanting in all of the species.

Pisum, Tourn.

Testa well developed. Pigment greenish-yellow, or brownish. Nutrient layer well-developed, thin-walled. Endosperm absent or appearing only as a remnant. Sempolowski wrongly called the inner part of the nutrient layer the endosperm. Schleiden and Vogel, and Chalon considered the seed of *P. sativum* as exalbuminous. Pringsheim, in 1848, gave a full account of the structure of the testa in his inaugural thesis. Sempolowski and Harz describe the species in detail. Russow studied only the light line. Tschirch and Oesterle, Tschirch, Hanausek, and other writers on food products, have described the testa and starch. The authors of numerous text-books on botany, like Hoffmeister, Strasburger, Sachs, and others, have given accounts of the starch and protein grains. Mattirolo and Buscalioni describe the anatomical characters of *P. thebaicum*, Willd. and *P. quadratum*. The germination of the common garden pea is described by Marek. Gray and other writers also describe its germination; Dahmen, the anatomy and physiology of the funiculus; Holfert, the nutrient layer; and Pfeiffer, the nature of the funiculus. Numerous chemical analyses have been made of the seed, which have been brought together by Harz, König, Jenkins and Winton; and Likiernik studied some of the special chemical products of the testa.

Pisum sativum, L.

Pl. XXX. f. 1.

Harz and other writers on economic food products have discussed the structure of the testa and cotyledons.

Malpighian. The cells are 96–100 μ long. The thin cuticle is uneven on the surface; the cuticularized layer is but slightly developed; light line occurs just below the enlarged points of the pore-canals; the cell-cavity is wide at the base, somewhat irregular, with one or more chromatophores.

Osteosclerid. The cells are 40–45 μ long, somewhat I-shaped, with small intercellular spaces; the walls are marked with longitudinal pore-canals, which, however, are not so pronounced as in *Lathyrus*.

Nutrient. This layer consists of 10 to 20 rows of elongated, thin-walled cells; in mature specimens this layer is much compressed, especially in the lower part.

Nucellus. Consists of a much compressed layer.

Endosperm. Much reduced and compressed.

Embryo. The epidermal cells of the cotyledons are much smaller than the underlying cells; they contain no starch, or very little; the underlying starch cells are large and irregular, with small intercellular spaces. These cells contain an abundance of starch grains which measure 14×16.8–19.6×25.2–$20.4 \times 36.4\ \mu$, each grain with a prominent rift in the center. It is well known that the cotyledons do not expand in germination as they do in *Phaseolus*, *Desmodium*, and many other *Leguminosae*. Palisade cells are uniformly present on the upper side in species where the cotyledons unfold, except in some *Phaseoleae*. In the pea the cells of the inferior and superior sides are similar.

Cicer, Tourn.

Harz, and Tschirch and Oesterle have described the structure of the common species. One of the striking features of this species is that the Malpighian cells have irregular lateral walls.

Cicer arietinum, L.

Pl. XXIX. f. 2–2c.

Testa 200–225 μ thick. Endosperm reduced or wanting. Starch is present.

Malpighian. Cells vary from 60–70 μ long, very irregular near the hilum, the surface of the seed in this region appearing minutely pubescent. Cuticle not strongly developed; cuticularized layer but slightly developed; the lateral walls very irregular below, thick above; light line in the upper part of the cell. Cell-cavity wide below. Walls color blue with chlor-iodide of zinc.

Osteosclerid. The I-shaped cells 20–33.5 μ long, with large intercellular spaces. Walls, except the middle lamella, color blue with chlor-iodide of zinc, the middle lamella, brownish.

Nutrient. This layer is differentiated into two parts; the upper consists of large cells with comparatively thin walls; the lower of small cells with thin walls.

Embryo. The epidermal cells are much smaller than the underlying parenchyma. The walls of the parenchyma are provided with pore-canals. The cells contain an abundance of spherical or elliptical starch grains and protein. Starch grains color blue with iodine, and the protein grains brownish. Starch grains vary from 16×22–56×10–22×16 μ.

Lens, Tourn.

Harz, in his Samenkunde, and Tschirch and Oesterle describe the microscopical characters of the lentil. The testa in some varieties is variously colored, in others yellowish-brown. Endosperm is reduced to a single row of cells, the aleurone layer. Starch is abundant in the starch layer.

Lens esculenta, Moench.

Pl. XXXIII. f. 3–3b.

Testa 190–200 μ thick, minutely roughened, the endosperm reduced.

Malpighian. Cells 40–45 μ long, slightly irregular on the surface as in the seeds of *Lathyrus;* light line in the upper part of the cell; lower part of the cell dark in color.

Osteosclerid. Cells 20–25 μ long, I-shaped only towards the hilum, otherwise nearly square, separated by wide intercellular spaces.

Nutrient. Parenchyma cells of the nutrient layer thin-walled; lower part more compressed than the upper. This layer contains the pigment.

Endosperm. Wanting except a single row of cells, the aleurone layer.

Embryo. The epidermal cells of the cotyledons small; the cells of the second row larger and containing less starch; the underlying parenchyma relatively thick-walled with pore-canals; the epidermal cells of the superior face are similar to those of the inner surface. Large starch grains abundant, with prominent rifts; they vary from 5×6–11×16–28×11μ. Green pigment is present in the cotyledons, as well as large procambial vessels, which are yellowish in color.

PAPILIONACEAE — Phaseoleae.

Apios, Moench.

Apios agrees with the other *Phaseoleae* in the poorly developed endosperm, and the presence of starch grains in the embryo.

Apios tuberosa, Moench.

Pl. XIX. f. 4.

Testa 140–145 μ thick.

Malpighian. Cells 52–56 μ long; light line close under the cuticle; cell-cavity large at the base, abruptly contracting near the light line; the cells are colored brown.

Osteosclerid. Cells are 15–18 μ long, I-shaped, separated by a small intercellular space.

Nutrient. This layer is compressed, divided into two parts. Cells of the upper part thin-walled and much larger than the thick-walled cells in the lower part.

Endosperm. Reduced to a single row, the aleurone layer.

Embryo. The epidermal cells are smaller than the underlying parenchyma, which has small intercellular spaces. All of the cells contain an abundance of small starch grains. They are much smaller than in allied genera. Aleurone grains are also abundant.

Mucuna, Adans.

The structure of the seed-coat is by no means uniform in the different species of the genus. In *Mucuna urens*, studied by the writer, the brown Malpighian cells are long, and coriaceous. The cuticle is also well defined. The nutrient layer is well developed and not compressed as in many other genera of *Leguminosae*. The structure of the entire seed indicates adaptation for dissemination by water. The Malpighian cells of *Mucuna pruriens* are less coriaceous, and the cells of the nutrient layer are more compressed. Endosperm reduced. Cells of the cotyledons contain an abundance of large starch grains.

MUCUNA PRURIENS, DC.

Pl. XXIII. f. 4. Pl. XXVII. f. 1-1d.

Malpighian. In the region of the hilum there is a double row of cells; the light line occurs under the cuticle, and a second indistinct line near the base of the cell.

Osteosclerid. In the hilar region the I-shaped cells are much like the spongy parenchyma of the nutrient layer, elsewhere greatly elongated, with large intercellular spaces.

Nutrient. Layer divided into two parts; the cells of the upper part with thicker walls, and larger than those of the lower.

Endosperm. Sparingly developed.

Embryo. The epidermal cells have thick exterior walls, and are much smaller than the underlying cells; palisade cells wanting. The cells contain large starch grains as well as aleurone grains.

PHASEOLUS, Tourn.

Many of the cultivated species have been studied because of their economic importance. Schleiden and Vogel, Chalon, Harz, Nadelmann, Tschirch and Oesterle, Tschirch, Nobbe, Tautphoes, Le Monnier, Hartig, Pringsheim, Sachs, Likiernik, Brongniart, Mattirolo and Buscalioni, Haberlandt, Löhr, Strasburger, Huss, Schröder, Mirbel, Strandmark, Hanausek, and the writer, as well as numerous others, have given accounts of the seed or parts of it in this genus.

Testa variously colored, brown, purple, red, and whitish, usually well-developed. The osteosclerids are usually I-shaped, with large intercellular spaces, although in *P. vulgaris* the cells are uniformly prismatic, thinner-walled, and contain a single one or a pair of large calcic oxalate crystals; these sometimes also occur in *P. multiflorus* but in this species the layer has intercellular spaces. These crystals do not occur in *P. lunatus* or *P. perennis* nor were they found by Haberlandt or Harz in *P. inamoenus* and *P. Mungo.* Nor does Harz record crystals in *P. acutifolius*, nor Strandmark in *P. ornithopus.* The nutrient layer is much compressed, and in the colored species and varieties it is abundantly pigmented. The mycotic cells occur in *P. multiflorus*, *P. vulgaris*, and

P. inamoenus. Haberlandt speaks of these as "verfilzten Zellen." Endosperm is but sparingly developed, usually consisting of a row of tabular cells, the aleurone, followed by one or more rows of thick-walled cells. The nucellus is reduced. The embryo contains fat, protein, and starch. Poorly developed palisade cells, scarcely to be distinguished from the parenchyma, occur on the upper face of the cotyledon in some species, but are usually absent. For the numerous chemical analyses, Harz, König, and Jenkins and Winton should be consulted.

PHASEOLUS PERENNIS, Walt. (*P. polystachyus*, L., BSP.) *Pl. XXI. f. 5–5b.*

Brown testa and endosperm 132–265 μ thick. The upper part of the nutrient layer variable.

Malpighian. Cells are 109–115 μ long. Cuticle slightly uneven; cuticularized layer poorly developed; several pores project into the walls from the cuticularized layer, to the light line or in some cases much beyond; the light line is narrow and occurs under the cuticularized layer. Cell-cavity is large at the base, gradually tapering upward, irregular in outline; small remnants of protoplasm occur in the cavity, and also considerable brown pigment and tannin.

Osteosclerid. The cells are thick-walled, 14 μ long, I-shaped, with large elongated intercellular spaces.

Nutrient. This layer is compressed and differentiated into two parts; cells of the upper part smaller, elongated and thinner-walled; in the hilar region it consists of star-shaped parenchyma with large intercellular spaces. Cells of the lower part are larger but variable. They contain a large amount of pigment and tannin.

Endosperm. Laterally a single row of cells, but in the micropylar region more strongly developed. The internal part of the endosperm consists of thick-walled elongated cells. These carry some protein grains.

Embryo. First row of cells smaller; exterior walls thickened; lateral walls are thinner; cells below the epidermis larger and more loosely arranged, with intercellular spaces in the angles. Upper portion of the cotyledon in germination with small epidermal cells much as in the lower part, followed by ordinary parenchyma. Procambial vessels not lignified. Cells contain an abundance of fat, protein, and large, stratified starch grains.

PHASEOLUS MULTIFLORUS, Willd.

Pl. XXI. f. 2–2g.

A full account of this seed is given by Mattiroio and Buscalioni. Tschirch and Oesterle, Harz, Holfert, and Haberlandt also treat the anatomy of the seed briefly. A general account is also given by Lubbock, and by Sachs, who studied its germination.

Holfert distinguishes five layers of the testa: (1) Malpighian, (2) osteosclerid, (3) obliterated nutrient layer, (4) star-shaped parenchyma, (5) obliterated star-shaped parenchyma (verfilzt). The testa is spotted, much larger than in *P. perennis*, laterally 580 μ thick, towards the edges 770 μ thick.

Malpighian. The cells are 84 μ long. Cuticle smooth; cuticularized layer not strongly developed; light line runs close under the latter; pores project into the wall below the light line. Cell-cavity large at the base, narrowed rather abruptly above. Walls of some of the cells as well as the cavity contain a bluish pigment, especially in the lower portion. The walls, cuticularized layer, and light line color blue with chlor-iodide of zinc.

Osteosclerid. Cell-walls thickened, longitudinally striated. Cells I-shaped, with elongated intercellular spaces. Cells contain some pigment.

Nutrient. Layer differentiated into two parts; cells of the upper portion thin-walled, loosely arranged, with numerous intercellular spaces; but little pigment present. Cells of the lower part narrower, thicker-walled, with more pigment, and tannin. Vascular elements occur in this part of the nutrient layer; these are also pigmented. The walls of the vessels give the reaction for lignin. The walls of the other cells of the nutrient layer color blue with chlor-iodide of zinc.

Mycotic. In cross-section the cells are closely packed and would pass for ordinary parenchyma; a tangential section, however, shows that the cells are elongated, somewhat star-shaped, and thick-walled. Cells strikingly resemble hyphae of fungi. These cells contain some protein.

Endosperm. Sparingly developed, usually a single row of cells, the aleurone layer, followed by thick-walled elongated cells with a small lumen. Cells contain fat and protein.

Embryo. Cells of the first row with thickened exterior walls; cells below more loosely arranged, larger than the epidermal cells, and with intercellular spaces in the angles; the cell-walls are thickened and connected with the adjoining cells by conspicuous pore-canals. Cells contain an abundance of protein, fat, and large starch grains with very evident stratification.

PHASEOLUS LUNATUS, L.

Pl. XXI. f. 1–1d.

The testa of this species has been studied by Haberlandt and Harz. Variable in thickness in the cultivated varieties, but much thinner than in *P. multiflorus*, 180–184 μ thick. Malpighian cells 60–61 μ long; cell-cavity wide at base and rather abruptly narrowed; light line close under the cuticle. Osteosclerids thick-walled, elongated, and somewhat funnel-shaped, intercellular spaces round or elongated. Nutrient layer consists of three to six rows of compressed cells, with vascular elements in the lower part. Cells in the outer row of the embryo are smaller; exterior walls thickened; cells below larger and more loosely arranged, and elongated, with intercellular spaces. The inner part of the cotyledon with parenchyma cells like the superior face. Cells of the cotyledons contain a great deal of starch, the large grains generally with longitudinal rifts. Also an abundance of protein and some fat.

STROPHOSTYLES, Ell. (*Phaseolus*, Kew Index.)

Testa variable, smooth or covered with hairs, otherwise much as in *Phaseolus*.

STROPHOSTYLES ANGULOSA, Ell. (*P. diversifolius*, Pers. Kew Index. *S. helvola*, L., Britton.)

Pl. XXI. f. 4.

Testa, including hairs, 332 μ thick.

Malpighian. Layer covered by a coat of brown hairs.

Cells thin-walled, usually as long as broad, obtuse, 106 μ long. Cell-cavity wide at the base, gradually tapering upward.

Osteosclerid. Thick-walled cells 19 μ long; intercellular spaces nearly square. Cells with a brown pigment.

Nutrient. Layer differentiated into two parts. In the upper part the cells are thin-walled and elongated, with large intercellular spaces; in the lower part they are smaller and thicker-walled.

Endosperm. The endosperm is reduced to the aleurone layer.

Embryo. The cells of the first row on the inner face are much smaller than the cells below. Cells of the second row are larger and compactly arranged; those of the interior are larger and more loosely arranged. The epidermal cells as well as those of the second row contain little or no starch. Walls of the cells of interior part of the cotyledons with pore-canals. The epidermal cells of the superior surface of the cotyledons are elongated, thick-walled, and contain no starch; palisade cells absent. Cells contain elliptical, spherical, or very irregular starch grains, aleurone grains, and fat.

STROPHOSTYLES PAUCIFLORUS, Watson. (*S. pauciflora*, Benth. Watson. *Phaseolus pauciflorus*, Benth. Kew Index.) *Pl. XXI. f. 3.*

Testa and endosperm 400–420 μ thick. Cuticle pronounced, covered with hairs; light line runs close under the cuticle; cell-cavity larger than in *S. angulosa;* cells contain an abundance of pigment and tannin. The intercellular spaces of the osteosclerids are elongated; the bars of the I-shaped cells are equal. The cells contain a great deal of tannin and pigment. Nutrient layer is as unequally developed as in the last species, with an abundance of vessels in the lower portion. Endosperm sparingly developed. The first row of cells, the aleurone layer, with thick walls, containing protein. Cells of superior face similar to those of inferior surface.

VIGNA, Savi.

Testa nearly colorless or pigmented, well-developed. The Malpighian cells are elongated; the thinner portions of the testa of *V. monachalis*, according to Harz, measure 22–24 μ long, and 33–90 μ in the hilar region. Osteosclerids are 13–24 μ long. Endosperm usually wanting. Embryo contains an abundance of starch and protein. The germination of *Vigna lutea*, Gray and *V. vexillata*, Benth. were studied by Lubbock.

VIGNA CATJANG, Walp. (*V. sinensis*, L., Endl.)

Pl. XXXIII. f. 1–1c. Pl. XXXIV. f. 3. Pl. XXXV. f. 9–10.

This species has been studied by Mattirolo and Buscalioni, Harz, Tschirch and Oesterle, and the writer.

Malpighian. Cells 55–57 μ long, nearly colorless in some varieties, in others with a bluish pigment; light line close under the poorly developed cuticularized layer; cell-cavity relatively large; an abundance of tannin present.

Osteosclerid. Cells are I-shaped and somewhat widely separated by the elongated intercellular spaces.

Nutrient. The cells of this layer have thin walls and are much compressed.

Endosperm. This is reduced to a single row of cells, the aleurone layer.

Embryo. The epidermal cells are smaller than underlying parenchyma, and contain only protein. The cells of the second row are somewhat larger, containing starch; intercellular spaces at the angles of the cells. The parenchyma below consists of large cells, their walls with pore-canals; they contain an abundance of large and small spherical or somewhat elliptical starch grains. Aleurone grains with one globoid. The nucleus may be readily made out when treated with iodine. Palisade cells are absent.

VIGNA GLABRA, Savi.

Pl. XX. f. 3.

Testa spotted, 140–150 μ thick. Malpighian cells are 74–80 μ long. The light line occurs close under the cuticle. Pore-canals extend below the light line; the cell-cavity contracts rather abruptly. The osteosclerids are of the usual type, I-shaped. The nutrient layer consists of five or more rows of cells. The mycotic layer is very narrow. The endosperm is much reduced, consisting of the well-defined aleurone layer. Epidermal cells of the inner face of the cotyledons much smaller than the underlying parenchyma cells, containing no starch; second row of cells intermediate between the epidermal cells and the parenchyma below. Palisade pareuchyma wanting. Procambial bundles large, yellowish in color. Starch grains vary from 17.6×28–141×6.6–28×42 μ.

Dolichos, L.

Studies of the genus have been made by Godfrin, Schleiden and Vogel, Harz, Haberlandt, and Mattirolo and Buscalioni. All of the writers studied forms of *D. Lablab*. Schleiden and Vogel as well as Chalon state that the seeds are exalbuminous, but Harz found endosperm sparingly present. The seeds of the species are used in tropical countries like the seeds of *Vigna* and the Soy bean.

Dolichos Lablab, L.

Pl. XXXIII. f. 4.

Malpighian. Cells 125–135 μ long; walls strongly thickened; light line close under the cuticle; cuticularized layer but slightly developed; pore-canals extend considerably beyond the light line. Several chromatophores are present in the cavity.

Osteosclerid. Cells large, 40–52 μ long; walls not strongly thickened. Large intercellular spaces separate adjoining cells.

Nutrient. Layer much compressed; cells with comparatively thin walls.

Endosperm. Sparingly present, reduced to the aleurone layer.

Embryo. Epidermal cells much smaller than the parenchyma; cells of the second row larger than those of the first row, but smaller than the parenchyma cells.

Epidermal cells contain a number of aleurone grains but starch is absent; the parenchyma below has an abundance of starch. The grains are similar to those of *Vigna*. They vary from 10 to 21 μ, occasionally some 35–40 μ. The epidermal cells of the superior face of the cotyledon are much smaller than the underlying parenchyma; they contain no starch, but well-developed aleurone grains. Palisade parenchyma wanting. The third row of parenchyma cells of the inferior face longer than broad. Procambial vessels yellowish.

CENTROSEMA, Benth. (*Bradburya*, Raf.)

Testa smooth. Endosperm sparingly developed. Cotyledons with thick-walled, stratified cells, the reserve cellulose. Chalon found endosperm present.

CENTROSEMA VIRGINIANUM, Benth. (*B. virginiana*, L., Kze.) *Pl. XIX. f. 3. 5.*

Testa 150 μ, towards the ends 250 μ or more thick.

Malpighian. Cells nearly colorless, 56 μ long; cuticle an even layer; cuticularized layer inconspicuous; light line just below the latter; several pores extending into the wall below the light line. Cell-cavity large at the base, abruptly contracted near the light line, containing one or more chromatophores in the cavity. The cell-cavity is smaller in the upper third of the cells and large near the base.

Osteosclerids. The thick-walled cells 14 μ long, toward the hilum 60–65 μ long. I-shaped cells with upper and lower bars nearly equal. Intercellular spaces elongated.

Nutrient. This layer is composed of from three to twelve rows of thin-walled cells. Cells in the lower portion carry much more pigment and tannin than the upper.

Endosperm. The aleurone cells are continuous, followed by one or two rows of mucilaginous endosperm. The internal part of the endosperm consists of thick-walled elongated cells with a narrow lumen. Cells contain protein.

Embryo. Cells of the first row continuous and isodiametric, with exterior walls thickened and stratified. Cells below are larger, the stratified walls greatly thickened and provided with pore-canals. Although the germination of this species has not been studied, the thick-walled cells are without doubt analogous to the reserve cellulose in the cotyledons of other plants. The walls respond quickly to the test for cellulose, and are easily soluble in sulphuric acid. The cells contain no starch, but an abundance of fat and protein. Palisade cells wanting.

CLITORIA, L.

Schleiden and Vogel give a brief account of *Clitoria Ternatea*, L., in which they found thick-walled cells in the cotyledons. This is not characteristic in all the species. Chalon indicated the presence of endosperm in the genus. In both of our species endosperm is present. Schleiden and Vogel expressed some doubt with reference to endosperm. The general characters of the seed and the germination of the above species are given by Lubbock. Germination studies of *C. Mariana* were made by Holm. The raphe is absent. The chalaza occurs in the thickened part of the testa. The micropyle is adjacent to the hilum.

CLITORIA MARIANA, L.

Pl. XVIII. f. 4. Pl. XX. f. 1.

Testa and endosperm 230–235 μ thick, the former brown.

Malpighian. Cells are 70–74 μ long. Cuticle somewhat uneven; the narrow light line occurs close under the cuticle; cavity wide at the base, becoming very narrow in the middle. Pigment irregularly distributed — portions are deeply colored.

Osteosclerid. Cells are 22.4 μ long, thick-walled and elongated; cavity very much reduced; bars of the I-shaped cells nearly equal; intercellular space narrow and elongated. Cells contain pigment and tannin.

Nutrient. Layer differentiated into two parts. The cells of the upper part are thinner-walled, and contain less pigment than those of the lower portion. Vascular elements occur in the lower part of the layer.

Endosperm. The large aleurone cells are nearly isodiametric and continuous, thick-walled, containing protein. The aleurone layer is followed by the mucilaginous reserve cellulose. It is somewhat variable as to thickness; the internal layer consists of thick-walled, elongated cells, with a narrow lumen. The cells contain protein.

Embryo. Cells of the first row are smaller and form a continuous layer; epidermal cells of superior face like those of inner surface, exterior walls thickened; interior cells with thicker walls and provided with pore-canals. Palisade cells wanting. I do not hesitate to consider this reserve cellulose, because of its ready solubility. It is true that the crucial test would be a study of it during germination.

CLITORIA TERNATEA, L.

Testa and endosperm 415 μ in thickness. Pigment and tannin abundant in the Malpighian and lower portion of the nutrient layers. Malpighian cells 140 μ long, each cell with one or more chromatophores. Osteosclerids united or more or less separated. The I-shaped cells thick-walled. The cells of the lower part of the nutrient layer thicker-walled than those of the upper part. The aleurone layer of the endosperm thick-walled; the remainder as in *C. Mariana*. The first row of cells of embryo nearly isodiametric. The cells below are elongated and more loosely arranged. Cell-walls comparatively thin. All of the cells contain fat and protein but no starch.

AMPHICARPAEA, L. (*Falcata*, Gmel.)

Both of the species which I have studied contain endosperm, remnants of the nucellus, and an abundance of pigment and tannin. The osteosclerids are striated. Embryo contains fat and protein but no starch.

AMPHICARPAEA MONOICA, Nutt. (*F. comosa*, L., Kuntze.) *Pl. XVII. f. 3.*

Testa and endosperm 235 μ thick. An abundance of pigment in the Malpighian cells and nutrient layer. The species has been studied by Miss Schively, but her account is quite inaccurate in details. The light line, which is well-developed, is not shown in the figures nor described.

Malpighian. Cells 120–150 μ long, brown. Cuticle somewhat uneven; cuticularized layer not pronounced; light line below the cuticularized layer; several pores project into the walls below the light line. The cavity is wide at the base, gradually tapering upward, and is very narrow in the light line region.

Osteosclerid. Cells 40–60 μ long, well-developed, longitudinally striated, especially in the hilar region. I-shaped cells with the upper and lower cross-bars nearly equal. Cells contain some tannin and pigment.

Nutrient. This layer is differentiated into two parts. The upper portion consists of larger thin-walled cells. Cells in the lower part thicker-walled and containing some pigment. The vascular elements occur in this region.

Nucellus. This is much compressed.

Endosperm. As in all other genera of the tribe *Phaseoleae*, the endosperm is greatly reduced, consisting of a single row of cells, the aleurone layer, having very thick walls. The contents of the cells consist of granular protein.

Embryo. The exterior walls of the first or epidermal cells are thickened. The cells below are larger and more loosely arranged. All of the cells contain fat and protein.

AMPHICARPAEA PITCHERI, T. & G. (*Falcata Pitcheri*, T. & G., Kze.)

The anatomy of this species has been studied by Schively, and its germination by Hitchcock. Malpighian cells with a slightly irregular cuticle; cuticularized layer but slightly developed; the light line occurs close under the cuticularized layer; cells with an abundance of pigment which is soluble in water. Osteosclerids I-shaped, long, with a large intercellular space. Nutrient layer and endosperm much compressed. Epidermal cells of the cotyledons much smaller than the underlying parenchyma. Exterior walls much thicker than the lateral ones. The second row of parenchyma cells intermediate between the epidermis and the parenchyma of the inferior. Large aleurone grains imbedded in the oil plasma. Starch absent. Palisade cells wanting. — (Muscatine, Reppert, — Washington, D. C., Steele.)

GALACTIA, P. Br.

Endosperm reduced. Anatomically the genus shows close relationship to *Rhynchosia*. The germination of *G. glabella*, Michx., has been studied by Lubbock.

GALACTIA GLABELLA, Michx. (*G. regularis*, L., BSP.)

The yellowish testa and endosperm vary from 149–166 μ in thickness.

Malpighian. The cells are 70 μ long. Cuticle somewhat uneven; light line just under the cuticularized layer; cell-cavity large at the base, gradually tapering upward, narrow in the light line region.

Osteosclerid. The I-shaped cells thick-walled, 14–30 μ long; bars nearly equal except in the hilar region. Intercellular spaces elongated. Cells contain some pigment and remnants of the protoplasm.

Nutrient. Differentiated into two portions; in parts of the testa only one layer is evident; cells of the upper part are thick-walled and contain more pigment than the lower.

Mycotic. In some portions of the seed this layer is well developed and consists of thick-walled cells shorter than those of the nutrient layer. The cells contain remnants of protoplasm.

Endosperm. The thick-walled cells of the aleurone layer contain protein. The mucilaginous reserve cellulose is variable in thickness and not usually well developed; the internal layer consists of thick-walled, elongated cells with small cavity. Cells contain some protein matter.

Embryo. Epidermal cells are small; cells of the inner surface nearly isodiametric; epidermal cells on the superior face somewhat longer than wide; the exterior walls thickened. Walls of parenchyma cells thickened, with numerous pore-canals, the cells of the second row smaller than the underlying parenchyma. Cells contain an abundance of starch, fat, and protein grains, except the epidermal cells, where starch is absent. Palisade parenchyma absent.

GALACTIA PILOSA, Ell. (*G. volubilis*, L., Britton.)
Pl. XVII. f. 2.

This species does not differ essentially from *G. glabella*. Light line close to the cuticle. Nutrient layer divided into two parts. The endosperm consists of a single row of cells, the aleurone layer; the large parenchyma cells are thick-walled and contain large stratified starch grains.

GLYCINE, L.

The structure of the testa was studied by Haberlandt, Harz (2 : 693), and Tschirch and Oesterle. The common Soy bean runs into numerous varieties. Starch is absent. An abundance of fat and aleurone. Endosperm is sparingly developed.

GLYCINE HISPIDA, Maxim.

Pl. XXXII. f. 9–9b. Pl. XXXIII. f. 5–6.

Malpighian. Cells 50–60 μ long, the longest in the hilar region. Light line situated somewhat above the middle; cavity large at the base, gradually tapering upward. In dark colored varieties these cells are abundantly pigmented.

Osteosclerid. Cells 27–50 μ long, I-shaped. In hilar region nearly as long as the Malpighian cells, with large intercellular spaces.

Nutrient. The layer is much compressed, consisting of two parts: the outer, of larger cells more loosely arranged; the inner, of thin-walled and smaller cells. The cells of the nutrient layer are pigmented.

Endosperm. Endosperm is sparingly developed, the aleurone cells are large and contain protein. The remainder consists of thick-walled cells which contain small amounts of protein.

Embryo. The epidermal cells are smaller; exterior walls thickened, otherwise the walls of the cotyledons are thin. The cells underneath the epidermis of the inner face are larger, but much shorter than the underlying parenchyma; the third row of cells long; several rows of palisade cells on the superior face. The embryo contains no starch, but an abundance of fat and protein. The aleurone grains are imbedded in the oil plasma.

RHYNCHOSIA, Lour.

Endosperm reduced. Chalon states that the seeds are exalbuminous. The cotyledons contain an abundance of starch, the grains of variable size. *R. glandulosa* was studied by Schleiden and Vogel.

RHYNCHOSIA LATIFOLIA, Nutt.

Pl. XVII. f. 4.

Testa and endosperm 150–166 μ thick. The osteosclerids contain a great deal of pigment.

Malpighian. Cells 72–74 μ long, with very little pigment.

Cuticle well-developed; the narrow light line occurs below the cuticularized layer; cell-cavity wide at the base with a somewhat irregular outline, with one or more chromatophores and remnants of the protoplasm.

Osteosclerids. The thick-walled I-shaped cells 19–20 μ long. Contents of cells and walls are brown in color.

Nutrient. Differentiated into two parts; cells of the upper part thin-walled and larger than those of the lower portion. All of the cells contain pigment and tannin.

Endosperm. This usually consists of a single row of thick-walled, elongated cells. Cell-cavity contains protein matter.

Embryo. Epidermal cells much smaller than those below; exterior walls thickened; cells below elongated, with small intercellular spaces at the angles, the somewhat thickened walls with pore-canals. The cells contain an abundance of protein, some fat, and starch grains of various sizes. The starch grains color blue with iodine, and the walls, with chlor-iodine of zinc. — (McDonald Co., Missouri, Bush, Mo. Bot. Gard.)

CAESALPINIEAE — Bauhinieae.

Cercis, L.

Testa smooth and hard with strongly developed mucilaginous endosperm. Systematic works indicate the presence of endosperm. Schleiden and Vogel, and Chalon recorded it in *C. siliquastrum*. The mucilaginous reserve cellulose of this species was described by Nadelmann. Germination studies were made by Lubbock and Tubeuf.

Cercis canadensis, L.
Pl. XVII. f. 1–1b.

Testa and endosperm laterally 664–670 μ thick, toward the edges only 290 μ. Testa 174 μ laterally, on the ends 207 μ thick. Cotyledons narrow, 464 μ across. Chalon studied the species with reference to endosperm.

Malpighian. This layer nearly colorless; the chromatophores occur in the upper part of the cell. Cuticle is an even layer, followed by a narrow but well marked bright, colorless, cuticularized zone; the narrow upper light line extends across the cell below the cuticularized layer; the upper part of the cell-cavity is widened just above the lower light line; part of the cell above the upper light line separates readily from the remainder of the cell-wall. Below the enlarged upper part of the cell-cavity the Malpighian cell is more refractive than in the lower part. Cells contain in addition to the chromatophores numerous small protoplasmic granules.

Osteosclerid. Thick-walled cells not markedly different from the cells of the nutrient layer. Small intercellular spaces, adjacent to the Malpighian cells.

Nutrient. Layer is differentiated into two parts; thick-walled cells of the upper portion somewhat elongated or nearly isodiametric, with pore-canals, containing but little pigment; cells of the lower portion elongated, thick-walled, having small pore-canals.

Endosperm. This is copious, cartilaginous when dry, mucilaginous and nearly colorless when moistened; the cells of the aleurone layer are thick-walled and contain protein; layer below of variable thickness, consisting of ten or more rows of thick-walled, mucilaginous cells, with prominent pore-canals. The internal part consists of thick-walled elongated cells with a narrow cell-cavity, or some cells with thinner walls, containing remnants of protoplasm. Walls differentiated into three parts; the secondary and tertiary layers color blue with chlor-iodide of zinc; the primary wall is thin and not affected by this reagent.

Embryo. The epidermal cells are nearly isodiametric, with exterior walls thickened; the cells below are longer and more loosely arranged, with small intercellular spaces; palisade cells on the inferior face of the cotyledons; all of the cells contain protein and fat but no starch. Walls color blue with chlor-iodide of zinc.

CAESALPINIEAE — Cassieae.

CASSIA, Tourn.

Quite a large number of the species have been studied, but more especially the medicinal species. Schleiden and Vogel studied *C. stipulacea*, Soland., *C. Fistula*, L., *C. speciosa*, Schrad., and *C. reniformis*, G. Don; the latter was also studied by Pringsheim. Chalon studied seventeen species, but only with reference to endosperm, except *C. Fistula*, L., of which the Malpighian cells as well are described. His figures are somewhat diagrammatic. The height of these cells is simply compared with some other *Leguminosae* studied by him. Nadelmann studied the development and the mucilaginous endosperm of *C. Fistula*, L. and *C. corymbosa*, Lam. Tschirch and Oesterle studied *C. angustifolia*, Vahl. The mucilaginous endosperm of *Cassia* is also described by Tschirch in his Angewandte Pflanzenanatomie. Lubbock has studied the germination of *C. Fistula* L., *C. circinata*, Benth., and *C. obovata*, Coll. De Candolle's germination studies agree with those of Hitchcock and Holm. So far as studied, all the species of the genus agree in the mucilaginous endosperm, the sclerotic nutrient layer, and the but slightly differentiated osteosclerids. A second osteosclerid layer below the nutrient is followed by several rows of thin-walled cells — the inner testa. Starch is absent from the embryo, but there is an abundance of protein and fat.

CASSIA CHAMAECRISTA, L.

Pl. XX. f. 4–4e.

Testa and endosperm measure 160–265 μ in the narrow parts of the seed; in the wider parts, 415 μ. Cotyledons 400–415 μ across.

Malpighian. Cells 44.8 μ long. Cuticle thickened, brownish, followed by a wide cuticularized layer; the narrow light line occurs under the cuticularized layer; the upper third of the cell is more refractive; several pore-canals project into the walls beyond the wide refractive portion. The cell-cavity is wide at the base, gradually tapering upward, enlarging at the upper light line. The cells contain a large chromatophore with some protein and a little coloring matter.

Osteosclerid. The thick-walled cells are nearly colorless, 84 μ long, with a rather large intercellular space between adjacent cells; occasionally these cells are not essentially different from those of the nutrient layer.

Nutrient. Consists of thick-walled sclerotic parenchyma.

Walls with radiating pore-canals. The walls color blue with chlor-iodide of zinc.

Endosperm. The aleurone cells are thick-walled and contain small protein grains. They are followed by the thick-walled mucilaginous reserve cellulose. Reactions of the cell-walls similar to those of *Cercis canadensis.*

Embryo. First row of cells small, nearly isodiametric; cells below elongated, with small intercellular spaces; the embryo contains no starch but there is an abundance of fat and protein; palisade cells on the superior face of the cotyledons.

CASSIA NICTITANS, L.

Pl. XX. f. 2. Pl. XXXIV. f. 5.

Testa and endosperm 165–350 μ wide. Malpighian cells 50–53 μ long; the upper part of the cell contains more pigment; light lines as in *C. Chamaecrista.* The thick-walled osteosclerids are but slightly differentiated from the cells of the nutrient layer, 10–12 μ long. Nutrient layer well-developed, cells thick-walled and sclerotic, containing a brown pigment. The inner testa as in other members of the genus. The endosperm as in *C. Chamaecrista,* differentiated into aleurone, middle mucilaginous reserve cellulose, and internal layers. Embryo as in the last species. — (St. Louis, Mo., Pammel. — Ithaca, N. Y., Stewart.)

CASSIA MARYLANDICA, L.

Pl. XX. 5-5b.

Chalon studied the species with reference to endosperm. Testa and endosperm 500–530 μ thick. Malpighian cells 92.4 μ long, more deeply colored in the lower part. Cuticle and cuticularized layer well developed; the narrow light line occurs close under the cuticularized layer; the second light line is wider, and occurs 40 μ from the cuticle, although its position is somewhat variable. Pore-canals in two series, one in the light line region and a second below. Osteosclerids 20–22 μ long; walls plainly differentiated into two parts; the cell-cavity almost obliterated in some cells. The cells are as a rule I-shaped, containing pigment and tannin. Cells of the nutrient layer are sclerotic; the walls are brown, while the cell-cavities are much deeper in color. The first layer of the inner testa is made up of osteosclerids; followed by several rows of thin-walled parenchyma. Endosperm and embryo similar to *C. nictitans* and *C. Chamaecrista.* — (Cult. Mo. Bot. Gard., St. Louis, Pammel.)

CAESALPINIEAE — Eucaesalpinieae.

HOFFMANSEGGIA, Cav.

Chalon found endosperm in *H. falcaria*, Cav.; detailed studies, however, were not made. The character of the Malpighian cells shows that the genus is closely related to *Gymnocladus* and *Gleditschia*. The cotyledons also agree with these genera. In both of our species the endosperm is cartilaginous.

HOFFMANSEGGIA JAMESII, T. & G.
Pl. XIX. f. 2–2b.

Testa and endosperm are 225–250 μ thick; the cotyledons, 996 μ across.

Malpighian. The cells are 64.4 μ long. Cuticle is smooth; cuticularized layer well developed; the narrow upper light line occurs under the cuticularized layer; a broad and refractive zone occupies one-third of the upper part of the cell. The cell-cavity is wide at the base, gradually tapering upward. Pore-canals several, extending beyond the upper light line. The canals are enlarged in the upper part of the cell, giving this part of the cell a beaded appearance. Cells contain a yellow pigment, and numerous small grains consisting of protein.

Osteosclerid. Cells of the layer widely separated, with large intercellular spaces. Walls thickened, color blue with chloriodide of zinc.

Nutrient. This layer is not strongly developed. Cells are elongated, thick-walled but scarcely sclerotic as in *Cassia*. Its structure approaches *Apios*.

Endosperm. The aleurone layer consists of thick-walled cells, containing protein; the cells below are thick-walled with large pore-canals, and likewise contain protein. Internal layer with thick-walled cells and a small lumen. Usually only one layer of cells evident in the endosperm.

Embryo. First row of cells smaller; exterior walls thickened. Cells below much larger, thinner-walled, and more loosely arranged; palisade parenchyma on the inner face. The epidermal cells of superior face do not differ essentially from those of the lower. All of the cells contain an abundance of fat, and protein but no starch. All of the cell-walls color blue with chlor-iodide of zinc.

HOFFMANSEGGIA DREPANOCARPA, A. Gray.

In this species the testa and endosperm are 300 μ thick. Malpighian cells 50 μ long. The wide light line in upper part of layer is narrower than in *H. Jamesii.* Cells of the nutrient layer much less thickened than in *Cassia.* Aleurone layer forms a continuous envelope around the mucilaginous endosperm. Cell-walls of the reserve tissue differentiated into primary, secondary, and tertiary thickenings. Endosperm is cartilaginous but becomes mucilaginous on the addition of water. The first row of cells of the cotyledons have their exterior walls thickened. Cells below larger and more loosely arranged, containing fat and protein.

GYMNOCLADUS, Lam.

Seeds with smooth and hard testa. A large amount of cartilaginous endosperm. Cells of the sclerotic parenchyma of the nutrient layer in numerous rows. Inner testa as in *Gleditschia.* Cotyledons agree with those of *Gleditschia* and *Cassia.* My study of *G. canadensis,* made in 1885, was evidently overlooked by Nadelmann, who has given an excellent supplementary account of the structure of the coffee bean.

GYMNOCLADUS CANADENSIS, Lam. (*G. dioica,* L., Koch.)
Pl. XXV. f. 1–1g.

The testa is 230–235 μ thick. Endosperm variable in thickness but easily made out with the naked eye. Histologically it shows a close relationship to *Gleditschia.*

Malpighian. Cells 192–196 μ long with a wide, colorless, cross-striated band in the upper part; the prominent cuticularized layer occurs below the cuticle. Below the cross-striated zone the pore-canals enlarge; the light line occurs above the middle. The cells contain some pigment.

Osteosclerid. Thick-walled cells are 30–35 μ long; the upper and lower cross-bars nearly equal; small intercellular spaces between the bars.

Nutrient. Consists of thick-walled sclerotic cells; the walls of the outer part are darker colored than the interior.

Inner integument. The inner coat is much compressed and can be made out only on the addition of chloral hydrate to the section. It consists of a row of quadrangular cells followed by thinner-walled osteosclerid-like cells and ducts.

Nucellus. The nucellus is much compressed and consists of elongated cells with granular contents.

Endosperm. The cartilaginous endosperm consists of thick-walled cells which on the addition of water are converted into mucilage; the water causes the secondary walls soon after to become dissolved, leaving large intercellular spaces. The lower part of the endosperm consists of cells which are smaller, with less thickened walls. This is much compressed.

Embryo. The cells of the first row are elongated and smaller than the underlying. Numerous procambial vessels in the cotyledons, and, in some cases, well-formed spiral ducts. Palisade cells absent. Cells contain fat and protein, but no starch.

GLEDITSCHIA, Clayton. (*Gleditsia*, L.)

Because of the more easily accessible material, several species have been studied. Schleiden and Vogel, Huss, Harz, and Chalon made an examination of the following species: *G. caspica*, Desf., *G. triacanthos*, *L.*, *G. latisiliqua*, Lodd., *G. indica*, Pers., and *G. macracantha*, Desf., but only with reference to endosperm. Nadelmann gives a very full account of the mucilaginous endosperm of *G. caspica*.

All of the species are characterized by having a smooth hard testa; copious cartilaginous endosperm which on the addition of water becomes mucilaginous; sclerotic parenchyma; nutrient layer strongly developed and, as in *Gymnocladus*, an inner testa occurs. Cotyledons agree with *Cassia* and *Gymnocla-*

dus. Moser's chemical analyses of *G. glabra* are given by Harz and König. The seed contains 2.96 per cent. of fat; 20.94 of protein; and 51.68 of nitrogen-free extract, 21.24 of this being dextrose, and 41 converted by sulphuric acid into sugar.

GLEDITSCHIA TRIACANTHOS, L.

Pl. XIX f. 1–1b.

Harz, and Schleiden and Vogel give short accounts of the structure of the testa and the endosperm. Testa and endosperm 1135–1160 μ thick; the endosperm varies from 600–675 μ thick; the sclerotic nutrient layer is 300 μ thick; osteosclerids 25.2 μ long.

Malpighian. Cuticle thick; the straw-colored cuticularized layer is followed by the narrow light line; a wide refractive zone occurs below the cuticularized layer, with no evident pore-canals, which stains readily with haematoxylin. Below the wide refractive band the pore-canals are enlarged, then become narrow and project into the walls for some distance. Cells contain protoplasmic remnants and some coloring matter. The narrow light line is not stained with haematoxylin; the wide refractive zone stains, but less deeply than the remainder of the wall, and the basal part of the cells is less colored than the middle portion.

Osteosclerid. The walls are greatly thickened. Cell-cavity is small, almost disappearing where it is constricted. Intercellular spaces are small.

Nutrient. Cells variable in length, longer than broad. The sclerotic parenchyma brown, containing a great deal of pigment.

Inner integument. The osteosclerids and the underlying parenchyma are much compressed. The osteosclerids compose a single layer of cells, followed by several rows of elongated, thin-walled parenchyma. The inner integument readily separates from the outer testa, adhering to the endosperm.

Endosperm. The thick-walled cells of the aleurone layer form a continuous row around the mucilaginous reserve cells, these containing protein grains. The reserve tissue consists of thick-walled cells with large pore-canals; the internal part of the endosperm consists of thick-walled, elongated cells with a small lumen; all of the cells contain protein and fat.

Embryo. Epidermal cells smaller than the parenchyma below; exterior walls thickened, measuring 19–25 μ long by 11.2–25.2 μ wide; those below the outer epidermis are 30–60 μ long by 20–25 μ wide. The cells towards the procambial vessels are shorter. Several rows of palisade parenchyma under the epidermal cells of the inner face. Cells of the embryo contain protein and fat, but no starch. — (St. Louis, Pammel.)

GLEDITSCHIA MONOSPERMA, Walt. (*G. aquatica*, Marsh.) *Pl. XVIII. f. 2. Pl. XXXIV. f. 2, 9.*

Testa smooth and shining, with endosperm, 1245 μ thick. Endosperm 960 μ across. Sclerotic nutrient layer 112 μ across. Malpighian cells 92–93 μ long. Osteosclerids 20 μ long. Malpighian cells agree essentially with those of *G. triacanthos;* cuticle and cuticularized layer prominent; pore-canals conspicuously enlarged in the light line region; remnants in these canals color the same as the cell contents do; light line does not stain. Gentian violet stains the contents readily. Osteosclerids as in the last species. The sclerotic nutrient layer and the inner testa agree with those of *G. triacanthos.* Endosperm cartilaginous; walls differentiated into primary, secondary and tertiary thickenings. Embryo with palisade cells on the inner surface or superior face; cells of the procambial region small. — (St. Louis, Kellogg.)

CAESALPINIEAE — Amherstieae.

TAMARINDUS, Tourn.

The thick-walled cells of the cotyledons of *Schotia speciosa* and *S. latifolia* were described by Schleiden and Vogel, who state that the walls color blue with iodine. In this respect they are like those of *Tamarindus*, long ago studied by Schleiden, and since by many other investigators. The thick-walled cells of the cotyledons of *Schotia latifolia* and the dissolution of the aleurone grains were studied by Godfrin in his work on the comparative anatomy of the cotyledons and albumen. The germination of *Peltogyne* and *Hymenaea Courbaril* was studied by Lubbock; that of *Tamarindus*, by De Candolle in his memoir on the *Leguminosae.*

TAMARINDUS INDICA, L.

Pl. XXXIII. f. 2.

Malpighian. Cells are 190–210 μ long. Light line occurs close under the cuticularized layer; cell-cavity is wide at the base; several pores extend into the cells much beyond the light line.

Osteosclerid. The cells are brown, not essentially different from those of the upper part of the nutrient layer.

Nutrient. This layer is divided into three parts; the walls of the outer are thick and star-shaped; middle portion with thinner walls; the parenchyma cells of the lower part are large, with comparatively thin walls. Numerous intercellular spaces in the parenchyma. Some of the cells contain pigment.

Endosperm. This consists of several rows of small cells. This portion of the seed is much compressed.

Embryo. The epidermal cells are small, and occur in two or three rows, followed by smaller cells. The remainder of the embryo, the reserve cellulose, consists of thick-walled cells with pore-canals. Cells of the caulicle are smaller and thin-walled. Cells contain small protein grains. Starch is absent.

MIMOSEAE — Adenanthereae.

PROSOPIS, L.

The seed of the mesquit is surrounded by a papery aril.

PROSOPIS JULIFLORA, DC.

Pl. XVIII. f. 3–3d.

Testa and endosperm are well developed. Testa quite uniform in thickness. Endosperm somewhat variable.

Malpighian. The cells are thick-walled; cuticularized layer strongly developed, as in *Cassia;* light line occurs above the middle; pore-canals project into the cell-wall below the cuticularized layer; cell-cavity wide at the base, but a mere line above the middle. Cells contain tannin, protein, and chromatophores.

Osteosclerid. Cells somewhat I-shaped, longer than broad, with a small intercellular space. The cells are smaller than those of the nutrient layer.

Nutrient. Cells thick-walled. Sclerotic walls usually colorless. Cells contain tannin.

Inner integument. It is much compressed, but on the addition of chloral hydrate the thin-walled parenchyma cells expand.

Nucellus. This consists of two to four rows of compressed cells with granular contents.

Endosperm. This layer is variable in thickness and well developed. Aleurone cells are thick-walled, usually isodiametric; the cells below are thick-walled, consisting of reserve cellulose.

Embryo. Epidermal cells much smaller than the underlying parenchyma, those of the inferior face elongated and more loosely arranged than those of the superior face. Two rows of palisade cells on the superior face of the cotyledons. Starch absent; aleurone grains and fat abundant.

MIMOSEAE — Eumimoseae.

DESMANTHUS, Willd. (*Acuan*, Med.)

The structure is much the same as in *Gymnocladus*. Cartilaginous endosperm is abundant; inner testa also present. Starch is absent.

DESMANTHUS BRACHYLOBUS, Benth. (*Acuan Illinoensis*, Mx.) *Pl. XVIII. f. 1–1b.*

Testa, with endosperm, 445 μ thick, endosperm 282 μ thick. Cotyledons 664 μ across.

Malpighian. The cells are 50–52 μ long. Cuticle and cuticularized layer are brownish, bearing colorless projections; the cuticularized layer easily separates from the remainder of the cell; the rather wide light line occurs a little below the middle. Cell-cavity wide at the base, gradually tapering upward. Several pores extend into the wall below the light line, from the cuticularized layer.

Osteosclerid. The cells are 12–14 μ long, I-shaped and thick-walled. Cell-cavity small. Cells contain some pigment and tannin, color reddish with potassium hydrate.

Nutrient. This layer is much compressed, consisting of a few to sixteen rows of thick-walled cells; differentiated into two parts, cells of the upper part thicker-walled than the lower, containing more pigment than the thin-walled lower parenchyma. Cells contain some protein matter.

Endosperm. Aleurone layer forms a continuous row of thick-walled cells with an abundance of protein; the mucilaginous reserve cellulose thick-walled, with small pore-canals; the internal part of the endosperm consists of narrow, elongated thick-walled cells with a small lumen. The cells contain some protein but not nearly as much as the middle mucilaginous portion.

Embryo. Epidermal cells are much smaller than those below, in some cases nearly isodiametric, others 8.4×9.8 μ varying to 9.8×15 μ long. Exterior walls thickened; cells below much longer and more loosely arranged, 35–42 μ long. All of the cells contain an abundance of fat and protein but no starch, also stellate compound crystals of oxalate of lime.

SCHRANKIA Willd. (*Morongia*, Britton.)

SCHRANKIA UNCINATA, Willd. (*M. uncinata*, Willd., Britton.) *Pl. XVIII. f. 5.*

Testa and endosperm 85–100 μ thick.

Malpighian. The cells are 45–49 μ long. Strongly developed cuticle; a well developed cuticularized layer; the latter when treated with potash takes on a straw or brownish color. Cuticularized layer and the cuticle separate easily from the remainder of the cells; light line a little above the middle; the numerous pore-canals occur below the cuticularized layer and project into the walls below the light line; cell-cavity large at the base, narrowed rather abruptly. Cells contain an abundance of tannin and some protein matter.

Osteosclerid. The cells are thick-walled, 15–16 μ long. Cavity very much reduced, containing pigment and tannin.

Nutrient. Walls of the cells thickened, slightly colored; containing an abundance of pigment and tannin.

Endosperm. In the widest part 30 μ thick. The aleurone layer consists of smaller cells, the remainder, of thick-walled reserve cellulose.

Embryo. Epidermal cells smaller than the underlying parenchyma of the inferior face. Several rows of elongated palisade cells on the superior face. Cells contain fat and protein but no starch.

MIMOSEAE — Acacieae.

ACACIA, Tourn.

Anatomically the genus is closely allied to *Desmanthus* and *Cassia*. The thick-walled sclerotic cells of the nutrient layer are like those of *Cassia* and *Gymnocladus*. The endosperm is much reduced, nor is the inner integument evident.

ACACIA FILICINA, Willd. (*A. filiculoides*,* Cav., Trelease.) *Pl. XXX. f. 2–2b.*

Malpighian. Cuticle not well-developed; the cuticularized layer a narrow zone; light line in the upper third of the cell; cell-cavity wide at the base, becoming very narrow in the region of the light line.

Osteosclerid. Cells small, I-shaped, with a small cavity.

Nutrient. Layer is divided into two parts. Cells of the upper part thick-walled. Cells of the lower elongated and the walls not so thick.

Endosperm. Much reduced, consisting of a single row of cells, the aleurone layer.

Embyro. Epidermal cells of the cotyledons small, usually a little longer than broad. The parenchyma cells of the inner face much larger than those of the epidermis, with small intercellular spaces. A single row of palisade cells on the superior face of the cotyledons; these are smaller than the underlying parenchyma. Cells contain fat and protein.

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* This is an error in Britton and Brown's Illustrated Flora. Cavanilles (Ic. 1: 55. *pl. 78.* 1791) wrote *Mimosa filicioides* and is correctly quoted in Watson's Bibliographical Index. In Kew Index it is given as *Mimosa filicoides* Cav.

Synopsis of Tribes and Genera.

The following synopsis is based on the characters of the testa, endosperm, and cotyledons. I have followed the arrangement given by Bentham and Hooker in their "Genera Plantarum."

PAPILIONACEAE.

Podalyrieae.

Light line close under the cuticle; osteosclerids I-shaped; nutrient layer and endosperm well developed. Embryo contains fat and protein grains; starch is absent; palisade cells present.

1. Malpighian cells covered with resiniferous bodies.................................. *Baptisia*.
1. Malpighian cells not reisiniferous.......... *Thermopsis*.

Sophoreae.

Light line close under the cuticle; osteosclerids I-shaped; nutrient layer compressed; endosperm well developed. Palisade cells present.

1. Reserve material consists of fat and aleurone grains........................... *Cladrastis*.
1. Reserve material consists of fat, aleurone grains, and small starch grains............ *Sophora*.

Genisteae.

Light line close under the culticle; osteosclerids I-shaped; endosperm well developed or nearly absent. Palisade cells present or absent.

1. Endosperm nearly absent................... *Lupinus*.
1. Endosperm more developed (2).
2. Endosperm not copious.................. *Crotalaria*.
2. Endosperm copious (3).
3. Nutrient layer much compressed........... *Laburnum*.
3. Nutrient layer less compressed............... *Genista*.

Trifolieae.

Cuticularized layer of the Malpighian cells well developed; osteosclerids rhomboidal, with longitudinal pore-canals; endosperm gelatinous, rather copious; reserve material consists of aleurone grains, fat and small starch grains. Cotyledons with palisade cells.

1. Cone-like projections of the cuticularized layer absent......................... *Trifolium*.
2. Cone-like projections present. . *Medicago* and *Melilotus*.

Loteae.

Cuticularized layer well developed; osteosclerids I-shaped; endosperm evident, gelatinous. Cotyledons with palisade cells; starch absent............................*Hosackia.*

Galegeae.

Cuticnlarized layer of the Malpighian cells usually not prominent; osteosclerids I-shaped; endosperm various, usually evident; reserve material usually consists of aleurone grains and fat, exceptionally starch.

PSORALIEAE. Cuticularized layer and mycotic cells variable. Cotyledons with palisade cells.

1. Mycotic layer evident.......................*Psoralea.*
1. Mycotic layer not evident (2).
2. Cuticularized layer not greatly developed. Starch grains present or absent..*Dalea*, *Petalostemon* and *Amorpha.*

INDIGOFEREAE. Malpighian cells long; osteosclerids I-shaped; endosperm conspicuous. Cotyledons with palisade cells; starch absent............................*Indigofera.*

TEPHROSIEAE. Cuticularized layer not strongly marked; osteosclerids I-shaped; mycotic layer variable; endosperm reduced. Palisade parenchyma present or absent.

1. Lysigenetic cauals in cotyledons............*Tephrosia.*
1. Lysigenetic canals absent; an abundance of starch..................................*Wistaria.*

ROBINIEAE. Cuticularized layer strongly developed; osteosclerids I-shaped; endosperm well developed; starch absent..*Robinia.*

ASTRAGALEAE. Cuticularized layer narrow, osteosclerids I-shaped; endosperm well developed. Cotyledons with palisade cells.

1. Osteosclerids usually with longitudinal pores.................................*Astragalus.*
1. Osteosclerids without longitudinal pores (2).
2. Nutrient layer much compressed..........*Glycyrrhiza.*
2. Nutrient layer less compressed.............*Oxytropis.*

Hedysareae.

Malpighian cells usually well developed; osteosclerids I-shaped; endosperm variable, copious or reduced. Cotyledons usually with several rows of palisade cells. Reserve material consists of fat, aleurone grains and exceptionally starch as well.

CORONILLEAE. Light line removed some distance from the cuticle; osteosclerids I-shaped; nutrient layer compressed;

endosperm mucilaginous. Cotyledons with one or more rows of palisade cells; chlorophyll grains in the cotyledons. *Coronilla.*

EUHEDYSAREAE. Cuticle irregular, cuticularized layer sharply defined; endosperm reduced. Starch present. *Hedysarum.*

AESCHYNOMENEAE. Cuticularized layer narrow; osteosclerids I-shaped; nutrient layer much compressed; endosperm present, more or less evident.......... *Aeschynomene.*

ADESMIEAE. Malpighian cells absent, short, or well developed; osteosclerids well developed or scarcely differentiated from the nutrient layer; endosperm reduced. Palisade parenchyma of the cotyledons wanting or well developed. Reserve material consists of fat, starch, and aleuroue grains.

1. Malpighian cells wanting.............. *Chapmannia.*
1. Malpighian cells present (2).
2. Malpighian cells short and thin-walled (3).
2. Malpighian cells long and thick-walled........ *Zornia.*
3. Cotyledons contain starch................. *Arachis.*
3. Cotyledons do not contain starch......... *Stylosanthes.*

DESMODIEAE. Cuticularized layer inconspicuous, light line close under the cuticle; osteosclerids I-shaped; endosperm present, the amount variable. Cotyledons with several rows of palisade cells; starch absent.

1. Endosperm usually copious................ *Lespedeza.*
2. Endosperm less copious.................. *Desmodium.*

Vicieae.

Malpighian cells well developed, surface usually irregular, cells contain one or more chromatophores; osteosclerids I-shaped, large with longitudinal pore-canals; nucellus more or less evident; endosperm reduced. Epidermal cells of the cotyledons much smaller than those of the parenchyma, palisade cells absent. Reserve food material consists of fat, starch, and aleurone grains. It is difficult to differentiate *Vicia* and *Lathyrus.*

1. Cuticle slightly irregular on the surface........ *Pisum.*
1. Cuticle very irregular on the surface (2).
2. Lateral walls of Malpighian cells undulated...... *Cicer.*
2. Lateral walls not undulated....... *Vicia* and *Lathyrus.*

Phaseoleae.

Cuticularized layer inconspicuous, Malpighian cells usually long; osteosclerids usually I-shaped; mycotic layer evident, or reduced; endosperm nearly wanting. Epidermal cells much smaller than the underlying cells, palisade cells usually wanting. Reserve food consists of fat, protein, and starch or reserve cellulose.

GLYCINEAE. Osteosclerids I-shaped; endosperm reduced, palisade cells usually wanting. Reserve food consists of fat, aleurone grains and reserve cellulose.

1. Palisade cells present in cotyledons .... *Glycine.*
1. Palisade cells absent (2).
2. Cell-walls of cotyledons very thick........ *Centrosema.*
2. Cell-walls of cotyledons less thickened (3).
3. Cell-walls of cotyledons more or less stratified, with large pore-canals................ *Clitoria.*
3. Cell-walls of cotyledons with small pore-canals.............................. *Amphicarpaea.*

GALACTIEAE. Cuticle somewhat uneven, cuticularized layer present; Malpighian cells with cell-cavity large at the base; osteosclerids I-shaped; mycotic layer evident. Endosperm consists of the aleurone layer and several rows of small cells. Epidermal cells much smaller than those of the parenchyma. Reserve material consists of fat, starch, and aleurone grains. *Galactia.*

ERYTHRINEAE. Malpighian cells long; osteosclerids I-shaped; endosperm nearly wanting. Epidermal cells much smaller than those of the parenchyma, palisade cells present or wanting. Reserve food consists of starch, aleurone grains, and fat.

1. Starch grains large......................... *Mucuna.*
1. Starch grains small........................... *Apios.*

EUPHASEOLEAE. Malpighian cells usually long; osteosclerids usually I-shaped; nutrient layer well-developed; mycotic layer conspicuous or nearly wanting; endosperm nearly wanting. Epidermal cells of the cotyledons much smaller than those of the parenchyma. Reserve food material consists of starch, aleurone grains and fat.

1. Mycotic layer of testa conspicuous.......... *Phaseolus.*
1. Mycotic layer not conspicuous (2).
2. Surface of Malpighian cells covered with more or less deciduous hairs.......... *Strophostyles.*
2. Surface of Malpighian cells not covered with hairs (3).
3. Spongy parenchyma of hilar region greatly developed............................... *Dolichos.*
3. Spongy parenchyma of hilar region less developed .... *Vigna.*

CAJANEAE. Malpighian cells long; osteosclerids I-shaped; endosperm nearly wanting. Epidermal cells of the cotyledons much smaller than those of the parenchyma. Reserve material consists of starch, protein, and fat.......... *Rhynchosia.*

CAESALPINIEAE.

Bauhinieae.

Cuticularized layer well developed, Malpighian cells long; osteosclerids not essentially different from the parenchyma of the nutrient layer; endosperm copious, cartilaginous. Several rows of palisade cells in the cotyledons. Reserve food material consists of fat and aleurone grains.......... *Cercis.*

Eucaesalpinieae.

Cuticularized layer conspicuous, Malpighian cells usually very long; osteosclerids usually not essentially different from the cells of the nutrient layer except that they are strongly sclerotic; inner testa evident as a rule; endosperm copious, cartilaginous. Usually several rows of palisade cells. Reserve food material consists of fat and aleurone grains.

1. Palisade cells absent.................. *Gymnocladus.*
1. Palisade cells present (2).
2. Malpighian cells very long................ *Gleditschia.*
2. Malpighian cells relatively short........ *Hoffmanseggia.*

Cassieae.

Cuticularized layer evident, Malpighian cells variable as to length in different species; osteosclerids I-shaped or like the underlying sclerotic cells of the nutrient layer; inner testa much compressed; endosperm copious, cartilaginous. Cotyledons with palisade cells. Reserve food material consists of fat and aleurone grains......................... *Cassia.*

MIMOSEAE.

Amherstieae.

Cuticularized layer not evident, Malpighian cells long and thick-walled; osteosclerids not essentially different from the cells of the well developed nutrient layer; endosperm nearly wanting. Parenchyma cells of the cotyledons thick-walled. Reserve material consists of fat, aleurone grains and reserve cellulose.................................. *Tamarindus.*

Adenanthereae.

Cuticularized layer evident, Malpighian cells thick-walled, light line above the middle of the cell; osteosclerids I-shaped, small and compressed; nutrient layer of thick-walled sclerotic cells; inner integument much compressed; endosperm co pious and cartilaginous. Epidermal cells much smaller than those of the parenchyma, two rows of palisade cells. Reserve material consists of fat and aleurone grains........*Prosopis.*

Eumimoseae.

Cuticularized layer well marked, Malpighian cells thick-walled; osteosclerids I-shaped, reduced, and essentially like the sclerotic cells of the nutrient layer; epidermal cells of the cotyledons smaller than those of the parenchyma, palisade cells in several rows. Reserve material consists of fat and aleurone grains.

1. Osteosclerids I-shaped..................*Desmanthus.*
1. Osteosclerids not I-shaped................*Schrankia.*

Acacieae.

Cuticularized layer a narrow zone, Malpighian cells thick-walled, not greatly elongated; osteosclerids I-shaped; endosperm much reduced. Epidermal cells of the cotyledons smaller than those of the parenchyma, one row of palisade cells...*Acacia.*

SUMMARY.

Under the general head of macrosclerids I have discussed quite fully the Malpighian cells, with reference to the light line, which I believe to be chemically and physically modified. The light line occurs in widely separated orders. The Malpighian cell separates at the light line, that being a point of least resistance. The Malpighian cells are either lignified or consist of cellulose. In some cases the cells are only partially lignified. They are lignified in some *Leguminosae*, also in some other orders. These cells always contain tannin and usually some pigment. The cuticularized layer is well developed in *Medicago* and *Gymnocladus*. The function of the Malphighian cells is largely one of protection.

The osteosclerids vary in different tribes, as shown in the synopsis; they usually carry pigment and tannin. The walls are not infrequently provided with longitudinal pore-canals. The nutrient layer in the immature seed is well developed. When the seed reaches maturity this layer becomes much compressed, its function, that of supplying nourishment to the developing seed, ceases when the ripening process begins.

The mycotic layer is much compressed and may be looked upon as a nutrient layer in the developing seed. The cells of this layer are narrow and hypha-like in their appearance.

The inner integument is suppressed except in *Caesalpinieae.* It is evident here when the section is treated with chloral hydrate.

The nucellus is much compressed. In some genera, notably *Gymnocladus, Pisum* and *Lathyrus,* it is more evident.

The endosperm varies greatly; in the *Caesalpinieae* it is well developed, conspicuous also in some of the so-called exalbuminous seeds, like *Trifolium* and *Medicago.* The aleurone layer is universally present, though frequently not conspicuous. The endosperm is mucilaginous and consists of reserve cellulose.

The structure of the embryo varies greatly. The epidermal cells are smaller than those of the underlying parenchyma. The parenchyma may be more loosely arranged, as in *Vicieae* and many of the *Phaseoleae,* or there are well defined palisade layers present on the upper side of the cotyledons. It is possible to foretell the method of germination except in *Phaseoleae.* Some of these germinate hypogaeously. In all other cases, so far as I know, the presence of palisade cells corresponds to epigaeous germination. In the *Vicieae* studied, palisade cells are wanting; these germinate hypogaeously.

The reserve food consists of cellulose, starch, fat, and protein, but in the majority of species it consists of fat and protein only. Lysigenetic canals occur in *Tephrosia.* Procambial vessels present, usually without spiral ducts. Spiral ducts occur in *Gymnocladus, Vicia Faba,* and *Phaseolus multiflorus.*

In the systematic portion of the work, representatives of three suborders were studied, namely *Papilionaceae, Caesalpinieae,* and *Mimoseae.* From this study it is evident that these cannot be treated as three separate orders. The order *Krameriaceae,* which by some recent writers is placed between the *Caesalpinieae* and *Papilionaceae,* has little in common with the *Leguminosae.* Most of the *Adesmieae* are strikingly different from the other tribes of *Leguminosae.* Of the 23 tribes given by Bentham and Hooker, 16 were studied, embracing 59 genera and 103 species, fairly representative of the order.

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EXPLANATION OF ILLUSTRATIONS.

PLATES VII–XXXV.

The lettering is the same throughout unless otherwise stated. M = Malpighian cells. ll = light line. l = lumen. o = osteosclerid. n = nutrient layer. n′ = remnants of the nucellus. a = aleurone layer. ale = aleurone grains. en = endosperm. en′ = internal part of endosperm. em = embryo. s = starch grains. cot. = cotyledons. sp = spiral ducts. a′ = epidermal cells of cotyledons. cr = crystals. hy = hilar groove above tracheid island.

Plate VII. — I, *Baptisia leucantha:* light line close to the cuticle; osteosclerids large; remnants of the nucellus present; epidermal cells of embryo smaller than those of parenchyma; fat globules and protein grains in cells.— II, *Thermopsis caroliniana:* nutrient layer and nucellus as in *Baptisia;* endosperm differentiated into three parts.— IIb, lower part of endosperm.— IIc, embryo, epidermal cells, and parenchyma.

Plate VIII. — I, *Melilotus officinalis:* prominent conical points above the light-line. — Ib, palisade cells of the embryo, upper face. — Ic, a single cell of the endosperm with thick walls; small starch grains in embryo. — II, *Melilotus alba:* small starch grains in the embryo; thick-walled endosperm cell shown below the embryo. — III, *Medicago lupulina:* — IIIb, somewhat rhomboidal osteosclerids more magnified. — IV, *Medicago denticulata:* secondary and tertiary walls dissolved; small starch grains in the embryo. — IVb, single I-shaped osteosclerid. — V, *Melilotus officinalis:* general longitudinal view of the seed; osteosclerids, spongy parenchyma of the nutrient layer, endosperm, and two cotyledons.

Plate IX. — I, *Lupinus pusillus:* cuticle and cuticularized layer above the light-line; several chromatophores in Malpighian cells; spiral duct in the nutrient layer; nucellus present; endosperm reduced. — II, *Trifolium agrarium:* — IIb, cells of embryo. — III, *Lupinus albus.* — IV, *Lupinus* sp. figure traced from Malpighius, Anatom. Plant. — V, *Trifolium reflexum:* endosperm of thick-walled cells; small starch grains in embryo. — VI, *Trifolium pratense:* chromatophores in cell-cavity; thick-walled endosperm cells. — VIb, embryo.

Plate X. — I, *Sophora sericea.* — Ib, cells of embryo with small starch grains. — Ic, lower part of the endosperm. — II, *Genista tinctoria:* thick-walled endosperm cells. — IIb, cells of embryo. — IIc, aleurone grains in cells. — III, *Cytisus scoparius:* thicked-walled endosperm cells and a compressed layer next to the embryo. — IV, *Crotalaria sagittalis:* nutrient layer divided into two parts. — V, *Cladrastis tinctoria:* conspicuous cuticularized layer above the light line; thick-walled reserve-cellulose of the endosperm with pore-canals.

Plate XI. — I, *Psoralea floribunda:* osteosclerids much compressed. — Ib, a more enlarged view of the osteosclerids; mycotic layer well developed, brown; remnants of the nucellus at *n′*. — II, *P. cuspidata:* compressed nutrient layer below the osteosclerids; mycotic layer well developed, brown. — IIb, cells of the cotyledons with aleurone grains *o′*; intercellular space at *i*. — III, *Amorpha canescens:* cell-walls of the endosperm thick; the epidermal cells of the embryo smaller than those of the parenchyma below. — IIIb, palisade cells of the embryo, superior face. — IV, *P. melilotoides:* cell-walls of the osteosclerids thick; mycotic layer much reduced. — IVc, cells of the embryo with protein, fat, and small starch grains. — V, *Hosackia Purshiana:* reserve cellulose of endosperm with thick-walled cells. — Vb, embryo with palisade cells of the superior face of the cotyledon. — VI, *Amorpha fruticosa:* chromatophores in the Malpighian cell; the osteosclerids followed by the nutrient layer. — VIb, walls of the aleurone layer greatly thickened; cells of the lower part of the endosperm with thin walls.

Plate XII. — I, *Dalea alopecuroides:* — Ib, spiral ducts in the nutrient layer. — IIa. *Tephrosia hispidula:* gelatinous endosperm; small epidermal cells of embryo. — IIb, simple crystals *cr* in cotyledons below the epidermal cells. — III, *Petalostemon violaceus.* — IV, *Tephrosia virginiana:* reserve cellulose of endosperm; epidermal cells of the embryo smaller than the underlying cells. — IVc, lysigenetic canal with its surrounding cells. — V, *Dalea alopecuroides:* sections from different parts of seed. — VI, *Petalostemon candidus:* thick-walled cells of the endosperm below the nutrient layer. — VIb, embryo with protein grains and fat. — VII, *Dalea laxiflora:* thick-walled reserve cellulose of endosperm.

Plate XIII. — I, *Indigofera leptosepala:* endosperm differentiated into three parts. — Ia, embryo. — II, *Oxytropis deflexa:* cells of nutrient layer thick-walled. — III, *Astragalus mexicanus:* separated Malpighian cells with well-developed cuticularized layer and cuticle. — IIIb, surface view of the Malpighian cells. — IV, *Oxytropis Lamberti:* cells of aleurone layer thick-walled. — V, *Astragalus canadensis:* cells of aleurone layer large, followed by the gelatinous endosperm. — Vb, cell-cavity with chromatophore after the action of sulphuric acid.

Plate XIV. — I, *Robinia Pseudacacia:* — Ia, general view of cross-section of the seed showing different layers in position. — Ib, portion of upper part of Malpighian cell greatly magnified to show cuticularized layer *c* with pore-canals projecting into cell. — Ic, Malpighian cell showing light line in upper part. — Id, young Malpighian cell greatly magnified. — Ie, osteosclerids greatly magnified, showing longitudinal pore-canals. — If, cells of endosperm with thick-walled reserve cellulose. — II, *Wistaria frutescens:* general view, broad cuticularized layer above the light line; chromatophores in upper part of cells. — IIb, section through outer part of embryo; starch grains in the cells; the interior large, and showing intercellular spaces. — IIc, lower part of nutrient layer and mycotic layer. — IId, an oblique view of the Malpighian cells.

Plate XV. — I, *Desmodium canescens:* cells of embryo without starch; nutrient layer differentiated into two parts. — II, *Desmodium strictum:* three rows of cells of the nutrient layer, followed by the aleurone, and reserve cellulose of the endosperm. — IIIa, *Desmodium canescens:* superior face of cotyledons; small epidermal cells and palisade parenchyma below; cells contain fat and aleurone grains. — IIIb, *Lespedeza Stuvei:* embryo cells of lower face. — IIIc, endosperm. — IV, *Aeschynomene hispida:* nutrient layer differentiated into two parts; cells of the aleurone layer smaller than those of the reserve cellulose of the endosperm. — V, *Lespedeza virginica:* large chromatophore in the upper part of Malpighian cell; cells of aleurone layer smaller than those of the reserve cellulose. — VI, *Glycyrrhiza lepidota:* nutrient layer well developed; aleurone cells large; thick-walled cells of reserve cellulose below. — VII, *Hedysarum boreale:* well developed cuticularized layer above the light line; large chromatophore in the Malpighian cell; epidermal cells of the embryo large.

Plate XVI. — I, *Vicia sativa:* minute pore-canals below the cuticularized layer; upper part of the Malpighian cell light colored with a large chromatophore; osteosclerids with longitudinal pore-canals. — II, *Vicia sativa:* Malpighian cells irregular on surface; cross-section of spiral ducts in the nutrient layer; epidermal cells of the embryo without starch. — IIb, starch grains which have undergone disintegration. — III, *Lathyrus maritimus:*

irregular outline of cell-cavity and small pore-canals. — IV, *Lespedeza capitata.* — V, *L. Stuvei.* — Vb, *L. virginica:* thick-walled reserve cellulose of the endosperm. — Vc, *L. Stuvei:* aleurone layer and remainder of endosperm. — VI, *Vicia Faba:* Malpighian cells with lateral pore-canals. — VIb, *Lathyrus venosus:* thick-walled aleurone cells; starch grains stratified. — VIc, endosperm cells.

Plate XVII. — I, *Cercis canadensis:* osteosclerids not I-shaped; cells of nutrient layer very irregular; crystals in epidermal cells of the embryo. — Ib, lower part of the endosperm. — II, *Galactia pilosa:* showing compressed nutrient layer, and the mycotic layer below; large starch grains in embryo. — III, *Amphicarpaea monoica:* osteosclerids elongated, I-shaped; aleurone grains in cells of embryo. — IV, *Rhynchosia latifolia:* endosperm reduced, and epidermal cells smaller than those of the starch layer below; starch grains large and stratified. — V, *Chapmannia floridana:* testa delicate; e epidermal cells, light line absent; spiral ducts in nutrient layer.

Plate XVIII. — I, *Desmanthus brachylobus:* sclerotic cells of nutrient layer thick-walled; cells of the reserve cellulose in lower part of cells smaller; some of the cells of the embryo contain crystals of calcic oxalate. — Ib, cuticularized layer below cuticle. — II, *Gleditschia monosperma:* Malpighian cells with cuticle and cuticularized layer somewhat reduced; pore-canals extend to the light line; cells of the inner integument expanded after the addition of chloral hydrate; aleurone cells smaller than those of the reserve cellulose. — III, *Prosopis juliflora:* conspicuous cuticularized layer. — IIIb, expanded thin-walled parenchyma cells of the inner integument followed by the thick-walled cells of the nucellus and endosperm. — IIIc, superior face of the two cotyledons, showing palisade cells. — IIId, inferior face of cotyledons; walls of the epidermal cells thickened. — IV, *Clitoria serrulata.* — V, *Schrankia uncinata.*

Plate XIX. — I, *Gleditschia triacanthos:* the wide cuticularized layer below the cuticle; to the right a single Malpighian cell. — Ib, stratified reserve cellulose of endosperm. — II, *Hoffmanseggia Jamesii:* the nucellus reduced; endosperm divided into two parts. — IIb, embryo. — III, *Centrosema virginianum:* nutrient layer differentiated into two parts, nucellus reduced. — IV, *Apios tuberosa:* endosperm and nucellus reduced; the epidermal cells of embryo smaller than the underlying starch cells; the latter contain small starch grains. — V, *Centrosema virginianum:* thick-walled reserve cellulose of the cotyledons.

Plate XX. — I, *Clitoria Mariana.* — II, *Cassia nictitans:* thick-walled sclerotic cells of nutrient layer, followed by the compressed layer of the inner integument. — III, *Vigna glabra:* nutrient layer compressed; mycotic layer reduced; the endosperm consists of a single row of cells; the epidermal cells much smaller than those of the starch layer below. — IV, *Cassia Chamaecrista:* with two light lines; inner integument compressed or merging into the cells of nutrient layer. — IVb, IVc, isolated Malpighian cells. — IVd, embryo. — IVe, portion of the Malpighian layer; cells separating at the light line. — V, *Cassia marylandica.* — Vb, osteosclerids.

Plate XXI. — I, *Phaseolus lunatus:* osteosclerids with lateral projections. — Ib, single Malpighian cell, enlarged. — Ic, osteosclerid. — Id, cells of the embryo. — II, *Phaseolus multiflorus:* spiral ducts in nutrient layer. — IIb, Malpighian cells. — IIc, tangential view of osteosclerids. — IId, pore-canals in cell-walls of mycotic layer. — IIe, starch grains. — IIf, striae of osteosclerids. — IIg, group of cells of the mycotic layer. — III, *Strophostyles pauciflorus.* — IV, *Strophostyles angulosa:* epidermal cells *e'* above the Malpighian cells. — V, *Phaseolus perennis.*

Plate XXII. — I, *Stylosanthes elatior:* short Malpighian cells; endosperm of a single row of cells. — Ib, palisade parenchyma with crystals in cells. — Ic, surface view of Malpighian cells. — II, *Coronilla montana.* — III, *Arachis hypogaea:* Malpighian cells with a large cell-cavity; nucellus compressed. — IIIb, surface view of Malpighian cells. — IIIc, cells of embryo in region of caulicle. — IIId, a single cell of the embryo showing aleurone grain with a crystalloid and globoid. — IIIe, showing starch grains, and procambial vessels at *prc.* — IIIf, embryo from the inferior face. — IIIg, superior face of cotyledon.

Plate XXIII. — I, *Lathyrus sativus:* Malpighian cells irregular on the surface. — Ib, section through the caulicle. — Ic, single starch grain more magnified. — II, *Desmodium nudiflorum:* the arillate processes shown at *ar*, also the hilum and hilar groove; the spongy parenchyma below the funiculus; endosperm the darker shaded portion at the upper end of the cotyledons, and the spongy parenchyma below the Malpighian layer. — III, *Coronilla montana:* showing position of the procambial vessels as well as the palisade parenchyma, two cells with chlorophyll grains. — IV, *Mucuna pruriens:* longitudinal section in region of radicle; arillate process at *ar;* the large micropyle leading to the radicle, showing the root-cap *rc;* the vegetative point *vp*, the plerome *pl* and the periblem and dermatogen *d.*

Plate XXIV. — I, *Medicago sativa:* — Ib, surface view of endosperm cells. — Ic, more magnified view of Malpighian cell showing cuticle, cuticularized layer, and the narrow cell-cavity *l.* — Id, osteosclerids, somewhat magnified. — Ie, endosperm treated with dilute hydrochloric acid. — If, section through inferior face of cotyledon, showing small starch grains. — Ig, superior face of cotyledon with palisade cells. — Ib, section through procambial vessel. — II, *Medicago lupulina:* endosperm mounted in water, showing the dissolution of the cell-walls. — IIb, cross-section through a procambial bundle.

Plate XXV. — I, *Gymnocladus canadensis:* cuticle shown at *c;* the cuticularized layer at *cl.* — Ib, the inner integument shown at *ii* with osteosclerid-like cells in lower portion and remnants of the nucellus. — Ic, endosperm with partial dissolution of cell-walls. — Id, the two cotyledons in position. — Ie, lower portion of the endosperm. — If, spiral duct of the procambial bundle. — Ig, inferior face of the cotyledon.

Plate XXVI. — I, *Vicia americana:* large chromatophore in Malpighian cell. — Ib, starch grains more magnified. — Ic, surface view of osteosclerids from hilar region. — II, *Vicia Faba.* — IIa, two rows of Malpighian cells in hilar region. — IIb, two starch cells, showing surface view of pore-canals in upper, and starch in lower cell. — IIc, cells of nutrient layer, one cell densely filled with pigment; cell below with remnants of protoplasm. — IId, spiral duct in cotyledon. — IIe, double Malpighian layer and tracheid island *tr.* — IIf, osteosclerids from the hilar region — IIg, surface view of osteosclerids. — IIh, endosperm. — IIj, upper figure, inferior face of cotyledons; the epidermal cells contain leucoplastids: lower figure, superior face of cotyledon.

Plate XXVII. — I, *Mucuna pruriens:* section through hilum with the two arillate processes *ar* made up of elongated sclerotic cells; the hilar groove *hg;* spongy parenchyma surrounding the tracheid island except the two rows of thin-walled cells which form a sheath about the island. — Ib, an oblique section, showing a general view of the micropyle, radicle, tracheid island, and arillate processes. — Ic, shows a portion of the funiculus, the arillate processes, hilum, and collapsed parenchyma. — Id, asparagin crystals in cells of cotyledons. — II, *Phaseolus vulgaris:* crystals in osteosclerid layer; epidermal cells of the embryo contain no starch.

Plate XXVIII. — I, *Lathyrus odoratus:* Malpighian cells irregular on the surface; nucellus compressed. — Ib, portion of an isolated Malpighian cell in hilar region. — II, *Lathyrus latifolius.* — III, *Lathyrus sylvestris.* — IV, *Petalostemon candidus:* cotyledons, superior face with palisade cells. — IVb, inferior face of cotyledons. — IVc, endosperm. — V, *Lathyrus sylvestris:* spongy parenchyma of hilar region, showing peculiar cellulose thickenings of walls.

Plate XXIX. — I, *Tephrosia virginiana:* cross-section of cotyledon showing position of the lysigenetic canals. — Ib, the lysigenetic canal after treatment with chlor-iodide of zinc. — Ic, cross-section through cotyledon, superior face, after treatment with sulphuric acid and iodine.— Ie, different view of reservoir. — If, Ig, *Tephrosia leucantha:* lysigenetic canal. — II, *Cicer arietinum.* — IIb, embryo with starch grains. — IIc, Malpighian cells more magnified.

Plate XXX. — I, *Pisum sativum:* nutrient layer divided into two parts, epidermal cells of cotyledons much smaller than the starch cells. — II, *Acacia filicina:* cells of nutrient layer thick-walled; nucellus compressed. — IIb, two adjacent cotyledons of superior face showing palisade cells. — III, *Desmodium Dillenii:* inferior face of cotyledon; small epidermal cells and parenchyma below. — IIIb, two rows of palisade cells, upper face of the cotyledon; aleurone grains in cells.

Plate XXXI. — I, *Sterculia heterophylla:* Malpighian cells with two light lines; below the light lines a darker zone; above the Malpighian cells outer dark-brown cells of testa. — II, *Marsilia quadrifolia:* cross-section through the wall of sporangium; light line in middle of cell. — III, *Zizyphus vulgaris:* surface view of Malpighian cells shown at *ms;* minute canals from peripheral walls. — IV, *Sicyos angulata:* light line near the cuticle; cell-cavity with branched canals. — V, *Ipomoea tuba:* light line in upper part; cell-cavity very small; a row of small cells above the Malpighian layer, which act as a support for the hairs of the seed; an entire cell shown to the right. — VI, *Dracocephalum parviflorum:* epidermal cells; the Malpighian layer below with two light lines; several chromatophores in the cell-cavity; the cells of the nutrient layer are abundantly supplied with tannin.

Plate XXXII. — I, *Canna indica:* Malpighian cells with light line in middle. — II, *Geranium carolinianum:* small epidermal cells above the Malpighian layer; these cells with crystals. — III, *Gossypium herbaceum:* walls of Malpighian cells greatly thickened in lower part; cell-cavity only occurs in the upper one-third of the cell; two light lines. — IV, *Tilia pubescens:* light line in upper part of Malpighian cell. — V, *Malvastrum angustatum:* the epidermal cells, the supporting layer and Malpighian layer. — VI, *Nelumbo lutea:* Malpighian cell. — VII, *Adolphia californica:* light line in upper part of Malpighian cell. — VIII, *Ceanothus americanus:* the Malpighian cells followed by the nutrient layer. — VIIIb, surface view of

Malpighian cells. — IX, *Glycine hispida.* — IXb, embryo; fat globules *f*, and protein.

Plate XXXIII. — I, *Vigna Catjang:* Ib, embryo. — Ic, surface view of osteosclerids. — II, *Tamarindus indica:* parts of nutrient layer and embryo shown; cells of the embryo thick-walled. — III, *Lens esculenta:* surface view of Malpighian cells; somewhat irregular on surface. — IIIb, a few cells of the embryo. — IV, *Dolichos Lablab.* — V, *Glycine hispida: a'*, epidermal cells; aleurone grains in parenchyma cell; *el* lower surface, *eu* upper surface with palisade cells.

Plate XXXIV. — I, *Lathyrus venosus:* Malpighian cell immediately after the addition of chlor-iodide of zinc; light line, cuticularized layer and the walls of osteosclerids take on a blue color; starch grains blackish. — II, *Gleditschia monosperma:* thick-walled reserve cellulose cells of endosperm treated with chlor-iodide of zinc color blue; the contents, yellowish. — III, *Vigna Catjang:* Malpighian cell treated with sulphuric acid and iodine. — IV, *Desmodium canadense:* treated with sulphuric acid and iodine. — V, *Cassia nictitans:* treated with ferric chloride. — VI, *Nelumbo lutea:* chlor-iodide of zinc colors the walls blue; phloroglucin and hydrochloric acid give no reaction, the cell retains its normal color. — VII, *Rhynchosia phaseoloides:* Malpighian and osteosclerid cells treated with ferric chloride, give the reaction for tannin; light line remains unchanged. — VIII, *Canna indica* treated with phloroglucin and hydrochloric acid, no reaction. — IX, *Gleditschia monosperma:* Malpighian cells treated with chlor-iodide of zinc, walls colored blue, the wide light band in upper part of cell, straw-colored. — X, *Tropaeolum majus:* thick-walled cells from cotyledon treated with iodine color blue, the reaction for amyloid. — XI, *Geranium carolinianum:* treated with phloroglucin and hydrochloric acid; Malpighian cells retain their normal color; the cells below slightly lignified. — XII, *Marsilia quadrifolia:* no reaction on the addition of phloroglucin and hydrochloric acid; walls color blue with chlor-iodide of zinc.

Plate XXXV. — I, *Dracocephalum parviflorum:* Malpighian cell treated with phloroglucin and hydrochloric acid, walls strongly lignified, — II, *Sterculia heterophylla:* lower portion of wall strongly lignified. — III, *Lathyrus venosus:* Malpighian cells natural color; starch grains after the addition of iodine. — IV, *Ceanothus americanus:* Malpighian cells treated with phloroglucin and hydrochloric acid; walls strongly lignified. — V, *Gossypium herbaceum:* lower part of cells strongly lignified. — VI, *Sicyos angulatus:* Malpighian cells strongly lignified, except the light line and upper part of cell. — VII, *Ipomoea tuba:* treated with chlor-iodide of zinc. — VIII, *Ipomoea tuba:* treated with phloroglucin and hydrochloric acid; cells very slightly lignified; walls below the Malpighian layer lignified. — IX, *Vigna Catjang:* tracheid island and Malpighian cells lignified. — X, *Vigna Catjang:* single Malpighian cell from lateral part of seed, lignified. — XI, *Tilia pubescens:* lower part of cell strongly lignified; light line remains unchanged when treated with phloroglucin and hydrochloric acid. — XII, *Baptisia leucantha:* Malpighian cells slightly lignified, the osteosclerids less so.

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TABLE A.—REACTIONS OF MALPIGHIAN CELLS, EXCEPT LIGHT LINE AND CUTICULARIZED LAYER.

Name of Species.	Chlor-iodide of Zinc.	Sulphuric Acid and Iodine.	Phloroglucin & Hydrochloric Acid.	Chloral Hydrate.	Fuchsine.	Haematoxylin. Delafield.	Ferric Chloride.	Iodine.	Normal Color. Chemical Composition, and Reactions.
Gleditschia triacanthos.	Cell-walls color blue, deeper than osteosclerids.	Cell-walls color light blue, disintegrated. Walls separate at light line.	No reaction.	Swells and becomes clear.	Cell-walls color deeply.	Contents color deeply.	Colors bluish, deeper at base.	Content color brown. Walls light straw color.	Nearly colorless. Contains tannin. Walls consist of cellulose.
Astragalus canadensis.	Cell-walls color blue, deeper than osteosclerids. Chromatophores brown	Cell-walls color blue, rapidly disintegrated. Walls separate readily at light line.	No reaction.	Swells and becomes clear.	Colors readily.	Chromatophores stain deeply.	Colors bluish, becoming black.	Chromatophores color brown.	Yellowish, nearly colorless. Contain tannin. Cell-walls consist of cellulose.
Baptisia leucophaea.	Walls only partially colored blue, less conspicuous than osteosclerids.	Walls color blue, less rapidly than osteosclerids. Rapid disintegration.	Colors a light shade of red.	Swells and walls become very clear.	Colors readily.	Chromatophores stain deeply.	Colors bluish, becoming black.	Chromatophores color brown.	Nearly colorless. Contain some tannin. Cell-walls partially lignified, also consists of some cellulose in parts.
Medicago sativa.	Walls color blue, chromatophores brown.	Cell-walls color blue rapidly. Rapid disintegration.	No reaction.	Swells and becomes very clear.	Upper part of cell-walls colors rapidly.	Contents color deeply.	Colors bluish-black.	Chromatophores color brown.	Brownish-yellow, or nearly colorless. Tannin present. Walls consist of cellulose.
Vicia Faba.	Walls color blue rapidly, chromatophores brown	Cell-walls color blue. Rapid disintegration.	No reaction.	Swells and becomes clear.	Lower part deeply colored. Upper less deep.	Contents color deeply.	Colors bluish-black.	Chromatophores color brown.	Yellowish or in thin sections nearly colorless. Contains tannin. Walls consist of cellulose.
Vigna Catjang.	Walls but slightly colored.		Colors a light shade of red.	Swells and becomes clear.					Cell-wall partially lignified, some cellulose.

TABLE B.—REACTIONS OF CUTICLE, CUTICULARIZED LAYER, AND LIGHT LINE.

NAME OF SPECIES.	CHLOR-IODIDE OF ZINC.	SULPHURIC ACID AND IODINE.	PHLORO-GLUCIN & HYDRO-CHLORIC ACID.	CHLORAL HYDRATE.	FUCHSINE.	HAEMA-TOXYLIN.	FERRIC CHLORIDE.	IODINE.	CHEMICAL COMPOSITION.
Gleditschia triacanthos.	Cuticle unchanged. Cuticularized layer blue. Light lines blue but less rapidly than cell-wall.	Cuticle unchanged. Cuticularized layer blue. Light lines blue. Rapid disintegration except cuticle.	No reaction.	Cuticle does not swell.	No reaction except light lines faintly colored.	No reaction.	No reaction.	Cuticularized layer brown.	Cuticularized layer made up of cellulose. Light line, cellulose in part.
Astragalus canadensis.	Cuticle unchanged. Cuticularized layer blue. Light lines color blue slowly.	Cuticle unchanged. Cuticularized layer blue. Light line colors blue. Disintegration except cuticle.	No reaction.	Cuticle does not swell.	No reaction except light lines faintly colored.	Light line faintly colored.	No reaction.	Cuticularized layer brown. Light line faintly brown.	Cuticularized layer made up of cellulose. Light line, cellulose in part.
Medicago sativa.	Conical cuticularized layer colors blue rapidly. Light lines blue, lighter than remainder of wall. Cuticle unchanged.	Cuticle no change. Cuticularized conical layer blue. Light lines a light blue, lighter than cell-wall. Disintegration except cuticle.	No reaction.	Cuticle does not swell.		No reaction for cuticle. The cuticularized layer stains but slightly.	No reaction.	Cuticularized layer and light line faintly brown.	Cuticularized layer made up of cellulose. Light line cellulose in part.

TABLE C.— MICROCHEMICAL REACTIONS OF OSTEOSCLERIDS.

Name of Species.	Chlor-iodide of Zinc.	Sulphuric Acid and Iodine.	Phloro-glucin & Hydro-chloric Acid.	Chloral Hydrate.	Fuchsine.	Haema-toxylin.	Ferric Chloride.	Iodine.	Chemical Composition.
Astragalus canadensis.	Walls color blue. Plastic material brown.	Walls color light blue. Rapidly dis-integrated.	No reac-tion.	Swell and become clear.	Cell-walls color slightly, contents deeper.		Color bluish, turns black.	Contents color brown, walls less than chro-matophores	Tannin present. Walls made up of cellulose.
Baptisia leucophaea.	Walls only slightly blue colored.	Walls only slightly blue colored. Rapidly dis-integrated.	Upper walls colored a light shade of red.	Swell and become clear.	Cell-walls color slightly, contents deeper.		Color bluish, turns black.	Contents color brown.	Tannin present. Cell-walls partially lignified.
Tephrosia virginiana.	Walls color blue.	Walls color blue. Striae evident. Disinte-grated.	No reac-tion.	Swell and become clear.	Cell walls but slightly colored, contents deeper.		Brightly colored, turns blackish.	Contents color brown.	Tannin present. Walls made up of cellulose.
Vicia Faba.	Walls color blue.	Walls color blue. Disin-tegrated.	No reac-tion.	Swell and become clear.	Contents color deeper than walls.		Deeply colored especially in hilar region, bluish, becomes black.	Contents color brown.	An abundance of tannin. Walls made up of cellulose.

TABLE D.—MICROCHEMICAL REACTIONS OF NUTRIENT LAYER.

Name of Species.	Alcannin.	Chlor-iodide of Zinc.	Sulphuric Acid and Iodine.	Phloroglucin & Hydrochloric Acid.	Chloral Hydrate.	Fuchsine.	Haematoxylin. Delafield.	Ferric Chloride.	Iodine.	Normal Color, and Chemical Reactions Show
Petalostemon candidus.	None.	Walls color blue but more slowly than Malpighian cells. Vascular elements not colored blue.	Walls color blue except vascular elements. Rapid disintegration.	Vascular elements colored light shade of red, especially tracheid island.	Swells and becomes clear.	Walls color, contents more deeply.		Colors bluish, becoming blackish.	Contents color rapidly.	Tannin abundant. Walls consist of cellulose except vascular elements. Normally of a brownish color.
Coronilla montana.	None.	Walls color blue.	Walls color light blue. Rapid disintegration.	No reaction except vascular elements.	Swells and becomes clear.	Walls color, contents more deeply.	Walls color but slightly.	Colors bluish, becoming blackish.	Contents color brownish.	Vascular elements lignified. Walls consist of cellulose. Normally cells colored brownish. Tannin abundant.
Gleditschia triacanthos.	None.	Cell-walls do not color rapidly, and only slightly.	Cell-walls color blue but slightly, rapidly disintegrate.	Sclerenchyma cells slightly colored a light shade of red, also vascular elements.	Swells but little, becomes clear.	Walls but slightly colored, much less than Malpighian cell.		Colors bluish, becoming blackish, the outer and inner parts, most abundantly.	Contents color brown.	Layer brown, contains an abundance of tannin. Walls in part consist of cellulose and in part of lignin.

TABLE E.—MICROCHEMICAL REACTIONS OF COTYLEDONS.

NAMES OF SPECIES.	ALCANNIN.	CHLOR-IODIDE OF ZINC.	SULPHURIC ACID AND IODINE.	PHLOROGLUCIN & HYDROCHLORIC ACID.	CHLORAL HYDRATE.	FUCHSINE.	HAEMATOXYLIN. DELAFIELD.	FERRIC CHLORIDE.	IODINE.	NORMAL COLOR, AND CHEMICAL REACTIONS SHOW
Cassia marylandica.	Red.	Walls color blue.	Walls color blue. Rapid disintegration.	No reaction.	Aleurone grains broken up.	Aleurone grains colored.		No reaction.	Nucleus colored. Aleurone grains color brownish.	An abundance of protein and fat. Walls consist of cellulose. Tannin absent.
Lespedeza violacea.	Red.	Walls color blue.	Walls color blue. Rapid disintegration.	No reaction.	Aleurone grains broken up.	Aleurone grains colored. Procambial elements first.	Walls color.	No reaction.	Nucleus and aleurone grains color brownish.	An abundance of fat and protein. Walls consist of cellulose. Tannin absent.
Mucana pruriens.	Red.	Walls color blue.	Walls color blue. Rapid disintegration of walls and starch grains.	No reaction.	Aleurone grains broken up. Starch grains swell.	Aleurone grains colored.		No reaction.	Nucleus and aleurone grains color brownish. Starch grains blue.	An abundance of starch, some protein and fat. Walls consist of cellulose. Tannin absent.
Medicago sativa.	Red.	Walls color blue. Starch grains deeply.	Walls color blue. Starch grains blue. Rapid disintegration.	No reaction.	Aleurone grains broken up. Starch grains swell.	Aleurone grains and nucleus color rapidly. Walls resistant.	Contents of cells color more readily than walls.	No reaction.	Nucleus and Aleurone grains color brownish. This reagent alone colors the starch grains very pale blue.	An abundance of fat and protein. Small starch grains. Walls consist of cellulose. Tannin absent.
Tamarindus indica.	Slightly red.	Walls color bluish-black with this reagent. Dissolved.							Aleurone grains color brownish. Cellulose bluish.	Reserve cellulose, protein, and fat present.

TABLE F.—MICROCHEMICAL REACTIONS OF ENDOSPERM.

Name of Species.	Chlor-iodide of Zinc.	Sulphuric Acid and Iodine.	Hydrochloric Acid.	Potassic Hydrate	Ferric Chloride.	Iodine.	Phloroglucin & Hydrochloric Acid.	Water.	Fuchsine.	Haematoxylin. Delafield.	Chloral Hydrate.	Normal Condition, Chemical Reactions show
Astragalus canadensis.		Cell-walls color blue, rapidly dissolved.	Cell-walls rapidly dissolved.		No reaction.	Contents colored brownish. Cells light straw color.	No reaction.	Becomes mucilaginous, except walls of aleurone cells.	Contents color rapidly. Walls colorless.	Walls of mucilaginous reserve cellulose not colored.	Expands rapidly, becomes clear.	Cartilaginous, colorless, muco-cellulose. Contents, protein. Tannin absent, also starch.
Medicago sativa.	Walls color light blue.	Cell-walls color blue rapidly, walls of aleurone less rapidly. Walls rapidly dissolved.	Walls rapidly dissolved, except primary.	Not changed.	No reaction.	Contents colored brownish. Walls of aleurone cells light straw color.	No reaction.	Becomes mucilaginous, except walls of aleurone cells.	Contents color rapidly. Walls nearly colorless.	Walls of reserve cellulose not colored.	Expands rapidly, becomes clear.	Cartilaginous, colorless, muco-cellulose. Contents protein. Tannin and starch absent.
Gleditschia triacanthos.	Walls color light blue.	Cell-walls color blue, rapidly dissolved. Protein brown.	Cell-walls rapidly dissolved.	Not changed.	No reaction.	Contents of aleurone cells brownish, conspicuous. Walls light straw color.	No reaction.	Walls of reserve cellulose become mucilaginous.	Contents color. Walls colorless.	Walls of reserve cellulose not colored.	Expands rapidly, becomes clear.	Cartilaginous, colorless, muco-cellulose. Contents, protein. Tannin and starch absent. Aleurone cells with a large amount of protein.
Coronilla montana.	Walls color light blue. Aleurone darker. Long continued action causes middle lamella to color blue.	Walls color light blue, rapidly dissolved.	Cell-walls rapidly dissolved.	Not changed.	No reaction.	Aleurone layer conspicuous. Contents brownish. Walls light straw color.	No reaction.	Mucilaginous except walls of aleurone cells.	Aleurone contents deeply colored. Walls colorless.	Walls of reserve cellulose not colored.	Expands rapidly, becomes clear.	Cartilaginous, colorless. Aleurone cells with a large amount of protein. Tannin and starch absent, muco-cellulose present.

TABLE F.—MICROCHEMICAL REACTIONS OF ENDOSPERM. — *Continued.*

NAME OF SPECIES.	CHLOR-IODIDE OF ZINC.	SULPHURIC ACID AND IODINE.	HYDRO-CHLORIC ACID.	POTASSIC HYDRATE.	FERRIC CHLORIDE.	IODINE.	PHLORO-GLUCIN & HYDRO-CHLORIC ACID.	WATER.	FUCHSINE.	HAEMATOXYLIN. DELAFIELD.	CHLORAL HYDRATE.	NORMAL CONDITION, CHEMICAL REACTIONS SHOW
Tephrosia virginiana.	Walls of aleurooe layer color blue rapidly. Reserve cellulose light blue.	Walls of aleurone layer blue. Reserve cellulose light blue. Rapidly dissolved.	Cell-walls rapidly dissolved.	Not changed.	No reaction.	Contents color brownish. Aleurone layer conspicuous. Walls light straw color.	No reaction.	Mucilaginous except walls of aleurone cells.	Contents color rapidly, in strong contrast with walls.	Walls of reserve cellulose not colored.	Expands rapidly, becomes clear.	Cartilaginous, colorless. Aleurone cells with a large amount of protein. Mucocellulose. Tannin and starch absent
Lespedeza violacea.	Walls of aleurone layer color blue rapidly. Reserve cellulose light blue. Middle lamella after long continued action blue.	Walls color light blue. Rapidly dissolved, except middle lamella.	Cell-walls rapidly dissolved.	Not changed.	No reaction.	Walls of aleurone cells light straw color. Contents brownish, Reserve cellulose. Walls light straw color.	No reaction.	Becomes mucilaginous, except walls of aleurone layer.	Contents of aleurone layer conspicuously colored.	Aleurone layer deeply colored. Walls of reserve cellulose not colored. Contents of reserve cellulose cells slightly colored.	Expands rapidly, becomes clear.	Cartilaginous, colorless. Aleurone cells with a large amonnt of protein. Mucocellulose. Tannin and starch absent.

TABLE G.— RELATION OF THE STRUCTURES OF THE CELLS OF THE COTYLEDON TO GERMINATION.

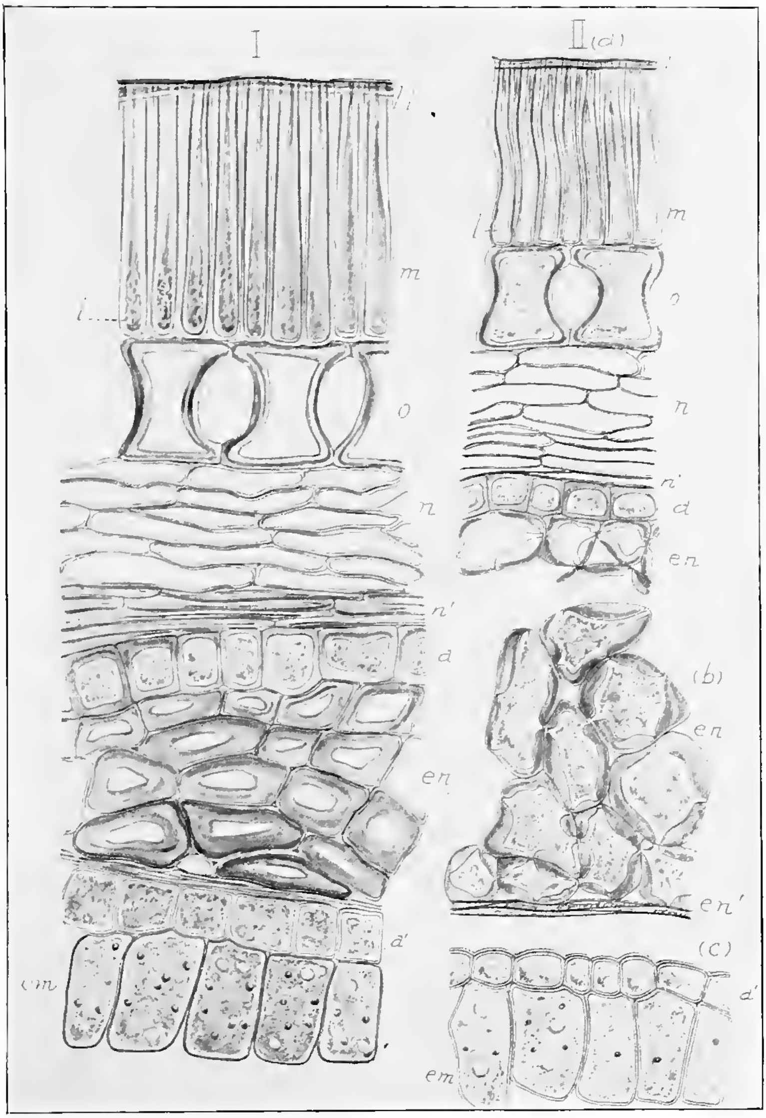
Name of Species.	Kind of Cells, Superior Face of Cotyledon.	Kind of Cells, Inferior Face of Cotyledon, with Contents.	Kind of Germination.	References to Germination Studies.
Baptisia leucantha. " *leucophaea.*	Several rows of palisade cells.	Parenchyma cells loosely arranged, starch absent.	Epigaeous.	De Candolle: *B. australis*, 84. *pl. 4. f. 4.*
Sophora sericea.	Several rows of palisade cells.	Parenchyma cells loosely arranged, small starch grains.	"	De Candolle: *S. japonica*, 83. *pl. 4. f. 1.*
Genista tinctoria.	Palisade cells, three to four rows.	Parenchyma loosely arranged, starch absent.	"	De Candolle: Sp. 80. *pl. 5. f. 6.* Lubbock, 409.
Lupinus pusillus.	Several rows of palisade cells.	Parenchyma cells loosely arranged, starch absent.	"	De Candolle: *L. angustifolia*, 107. *pl. 18. f. 94;* Lubbock: *L. arboreus*, 405. *f. 264;* *L. micranthus*, 406; *L. sulphureus*, 406.
" *luteus.*	One well-developed row of palisade cells.	Parenchyma cells larger, loosely arranged, starch absent.		
Medicago sativa.	Several rows of palisade cells.	Parenchyma cells loosely arranged, small starch grains present.	"	De Candolle: Sp. 88. *pl. 7. f. 15.* Lubbock: *M. orbiculatus*, 415. *f. 271;* *M. lupulina*, 415; *M. sativa*, 415.
Melilotus alba.	Several rows of palisade cells.	Parenchyma cells loosely arranged, small starch grains present.	"	Hitchcock: Bull. 50. 27. *f. 20.*
Hosackia Purshiana.	Two rows of palisade cells.	Parenchyma cells loosely arranged, starch absent.	"	Lubbock: *Lotus Tetragonolobus*, 419; *Anthyllis vulneraria*, 418. *f. 273.*
Psoralea melilotoides	Palisade cells, three or four rows.	Parenchyma loosely arranged, wider than palisade cells, starch absent.	"	De Candolle: *P. lathyrifolia*, 89. *pl. 7. f. 21;* *P. verrucosa*, 89. *pl. 7. f. 22.* Lubbock: Sp. 420.

TABLE G.—RELATION OF THE STRUCTURES OF THE CELLS OF THE COTYLEDON TO GERMINATION.—*Continued.*

NAME OF SPECIES.	KIND OF CELLS, SUPERIOR FACE OF COTYLEDON.	KIND OF CELLS, INFERIOR FACE OF COTYLEDON, WITH CONTENTS.	KIND OF GERMINATION.	REFERENCES TO GERMINATION STUDIES.
Indigofera leptosepala.	Three or four rows of palisade cells.	Parenchyma cells somewhat longer than broad, loosely arranged, starch absent.	Epigaeous.	De Candolle: 90. *pl. 7. f. 25.* Lubbock: *I. australis*, 420. *f. 274.*
Coronilla montana.	Palisade cells, two or three rows.	Parenchyma cells loosely arranged, starch absent.	"	De Candolle: 98. *pl. 12. f. 56–57.* Lubbock. *C. juncea*, 430; *Hedysarum denticulatum*, 431. *f. 279; H. coronarium*, 432. *f. 281.*
Desmodium Dillenii. " *canescens.*	Several rows of palisade cells.	Parenchyma cells with inter-cellular spaces, starch absent.	"	Hitchcock: *D. illinoense*, Bull. 50. 27. *f. 24.* Lubbock: *D. canadense*, 436. De Candolle: 100. *pl. 12–13. f. 53–68;* germination of nine species.
Lespedeza violacea.	Palisade cells, two to three rows.	Parenchyma cells with inter-cellular spaces, starch absent.	"	Holm: 67. *pl. 9. f. 43–44; L. procumbens, pl. 9. f. 45–46.* Lubbock: *L. angustifolius*, 437. De Candolle: 101. *pl. 14. f. 73.*
Stylosanthes elatior.	Palisade cells compactly arranged.	Parenchyma cells loosely arranged, starch absent.	"	
Vicia Faba. " *americana.*	Palisade cells absent.	Large parenchyma cells, contain starch.	Hypogaeous.	De Candolle: *Vicia*, 102. *f. 74–76.* Marek: 160, 167. . *69, 72–74.* Malpighi: 100. *f. 3.*
Lathyrus odoratus. " *sativus.*	" "	Large loosely arranged parenchyma cells, starch present.	"	De Candolle: 103. *pl. 15.* Lubbock: *L. Nissolia*, 437. *f. 284; L. Aphaca*, 439. *f. 285.*
Pisum sativum.	" "	Large parenchyma cells, starch present.	"	Malpighi: 102. *f. 4.* De Candolle: 107. *f. 78.* Marek: 153. *f. 47–53, 59–66.*
Lens esculenta.	" "	Large parenchyma cells, starch present.	"	De Candolle: 103. *pl. 15. f. 77.*
Phaseolus perennis " *vulgaris*	" "	Large parenchyma cells, starch present.	Epigaeous.	Lubbock: *P. vulgaris*, 446. *f. 290.* Malpighi: *98. f. 2.*

TABLE G.— RELATION OF THE STRUCTURES OF THE CELLS OF THE COTYLEDON TO GERMINATION.—*Continued.*

NAME OF SPECIES.	KIND OF CELLS. SUPERIOR FACE OF COTYLEDON.	KIND OF CELLS, INFERIOR FACE OF COTYLEDON, WITH CONTENTS.	KIND OF GERMINATION.	REFERENCES TO GERMINATION STUDIES.
Vigna lutea.	Palisade cells absent.	Large parenchyma cells, starch present.	Epigaeous.	Lubbock: 447.
Strophostyles angulosa.	" "	Large parenchyma cells, starch present.	"	Hitchcock: *Strophostyles pauciflorus*, Bull. 50. 27. *f. 25.*
Amphicarpaea Pitcheri.	" "	Large parenchyma cells, starch absent.	Hypogaeous.	Hitchcock: Bull. 50. 27. *f. 18.*
Cercis canadensis.	Several rows of palisade cells.	Parenchyma loosely arranged, starch absent.	Epigaeous.	Lubbock: *C. Siliquastrum*, 465. *f. 304.*
Cassia marylandica.	Several rows of palisade cells.	Parenchyma cells loosely arrangsd, starch absent.	"	De Candolle: Sp. *pl. 25. f. 115–119.* Lubbock: *C. circinata.* 459. *f. 299; C. obovata*, 460. *f. 300; C. Fistula*, 461. *f. 301–302.* Hitchcock: *C. Chamaecrista*, Bull. 50. 27. *f. 19.*
Gymnocladus canadensis.	Palisade cells absent.	Parenchyma cells large, starch absent.		
Gleditschia triacanthos.	Several rows of palisade cells.	Parenchyma cells loosely arranged, starch absent.	Epigaeous.	Tubeuf: 127. *f. 173.* De Candolle: 117. *pl. 22. f. 109.*
Prosopis juliflora.	Several rows of palisade cells.	Parenchyma cells loosely arranged, starch absent.		



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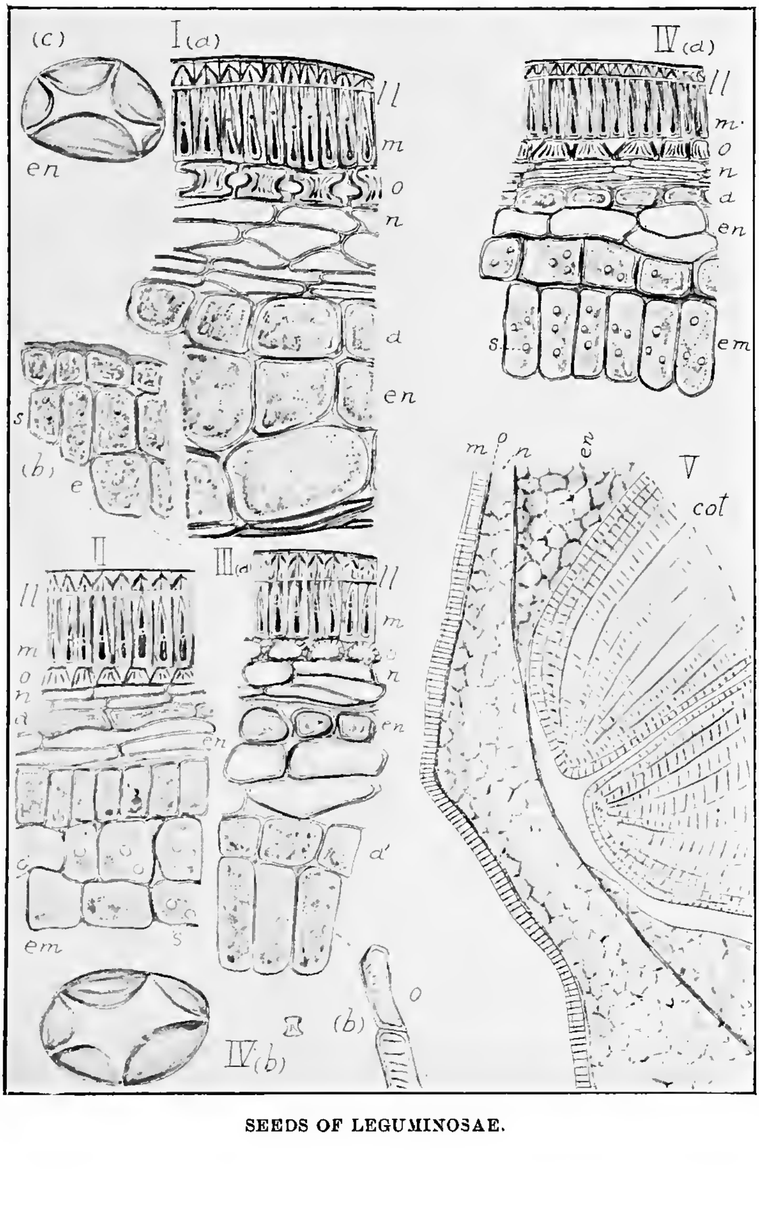

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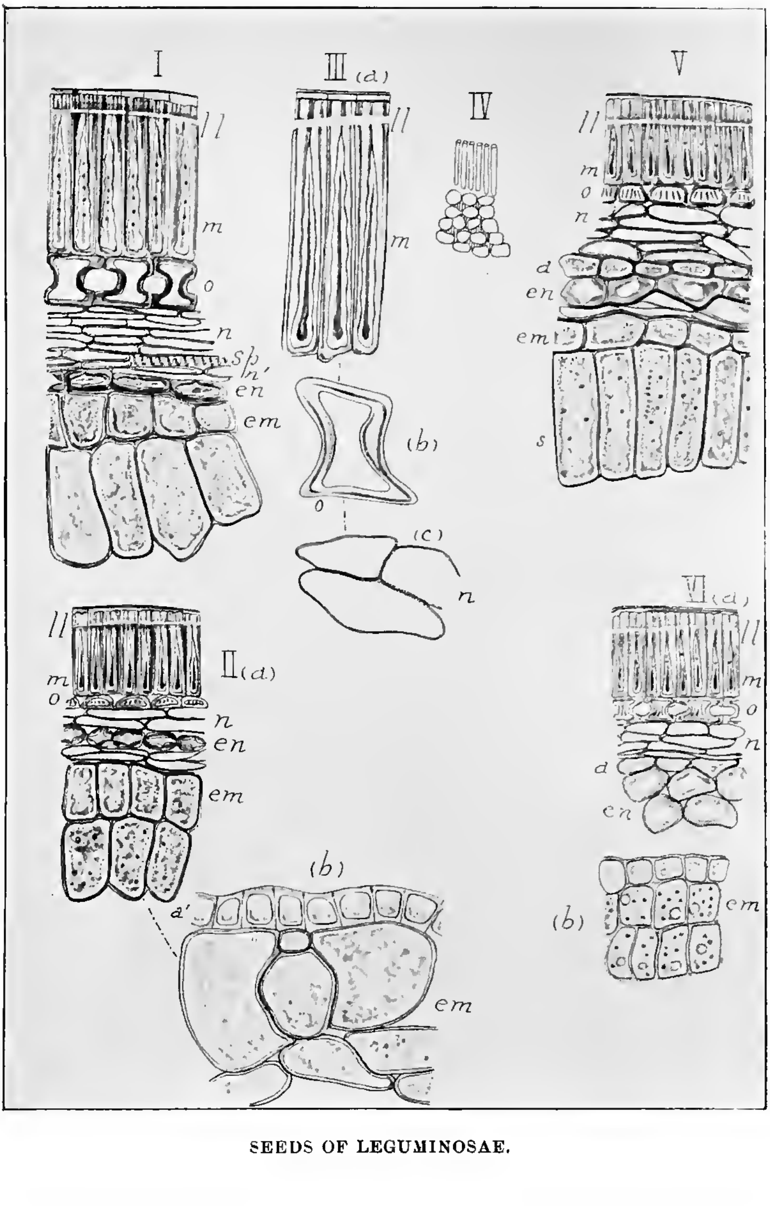

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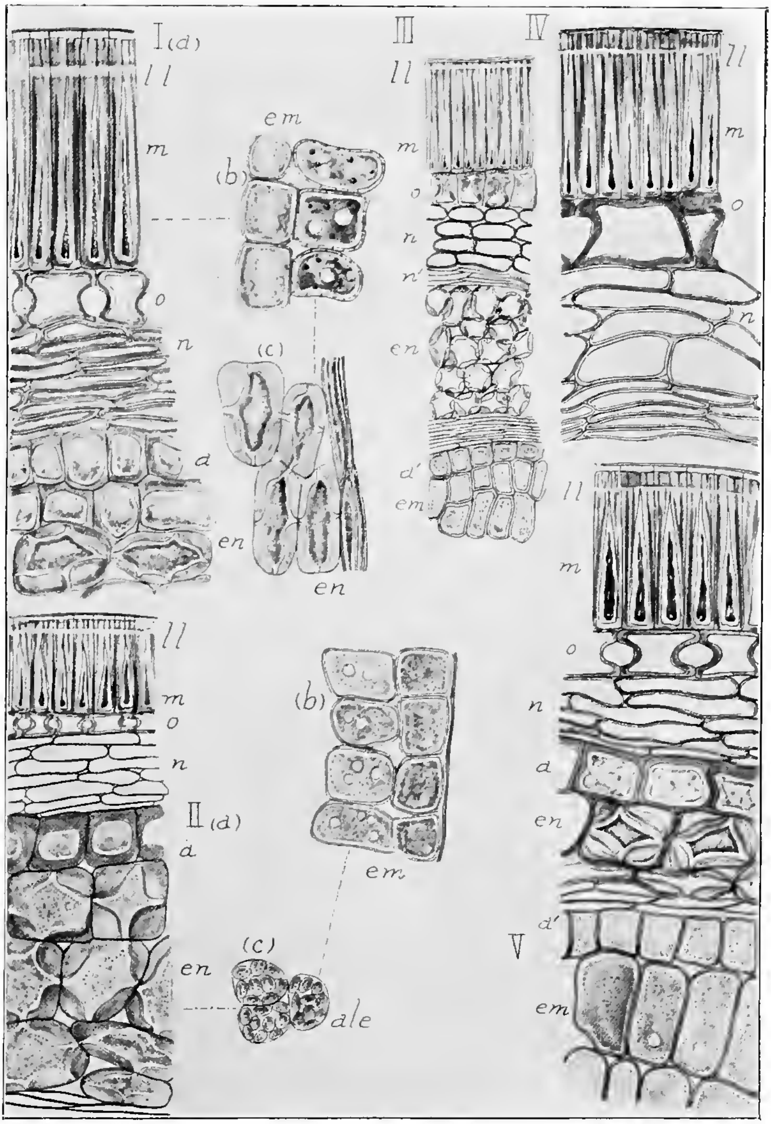

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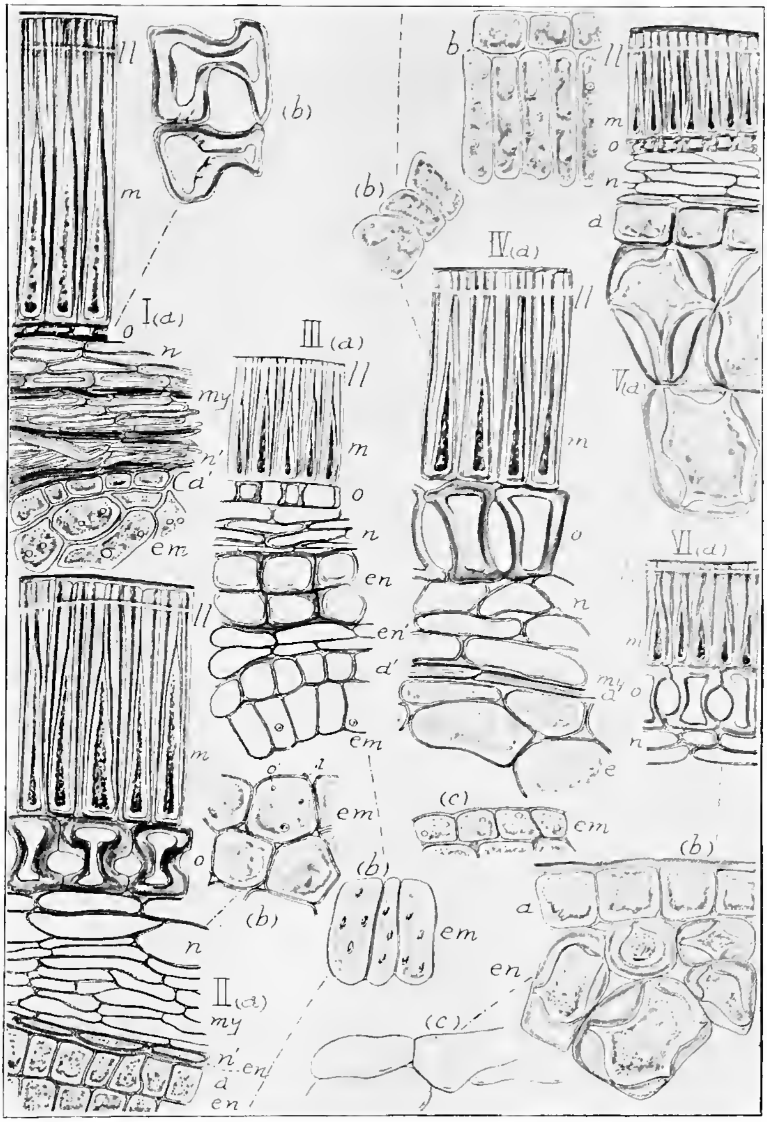

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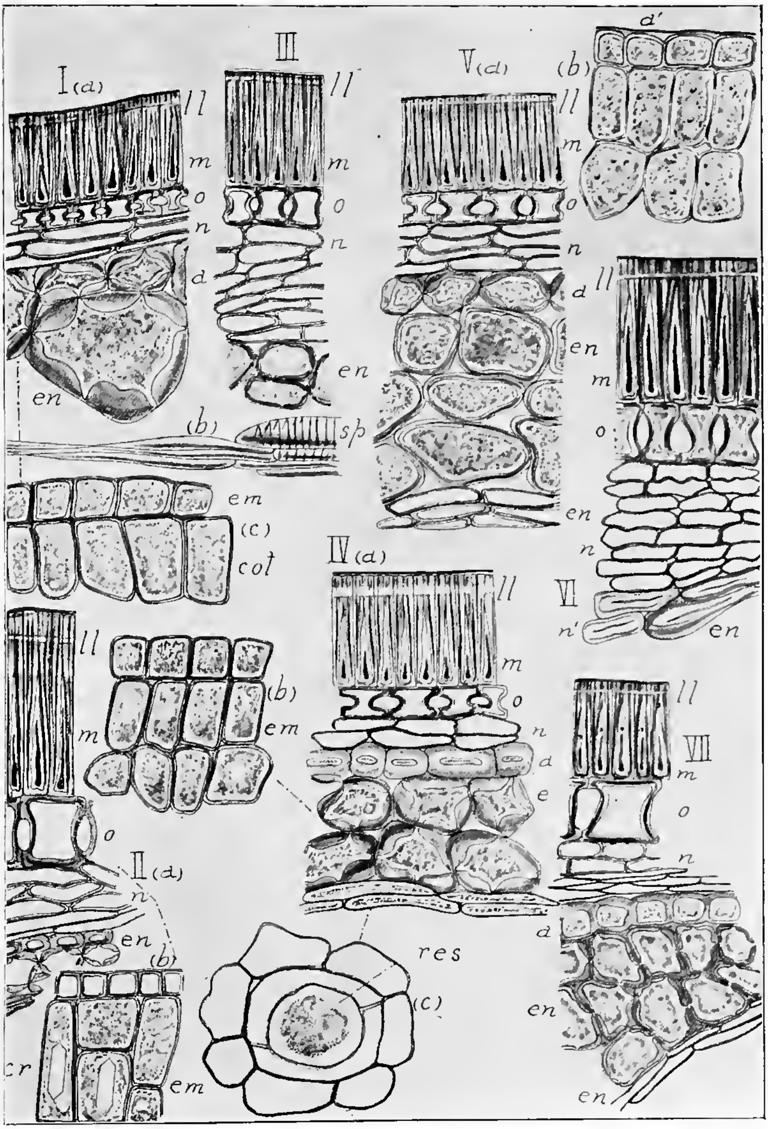

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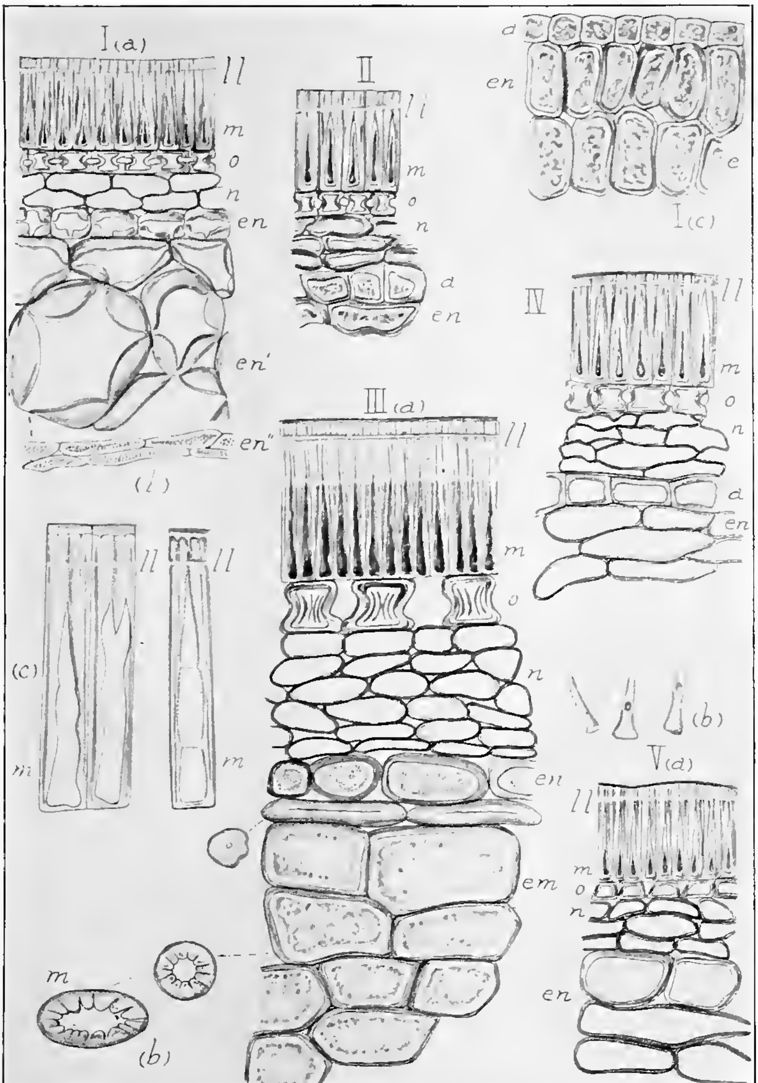

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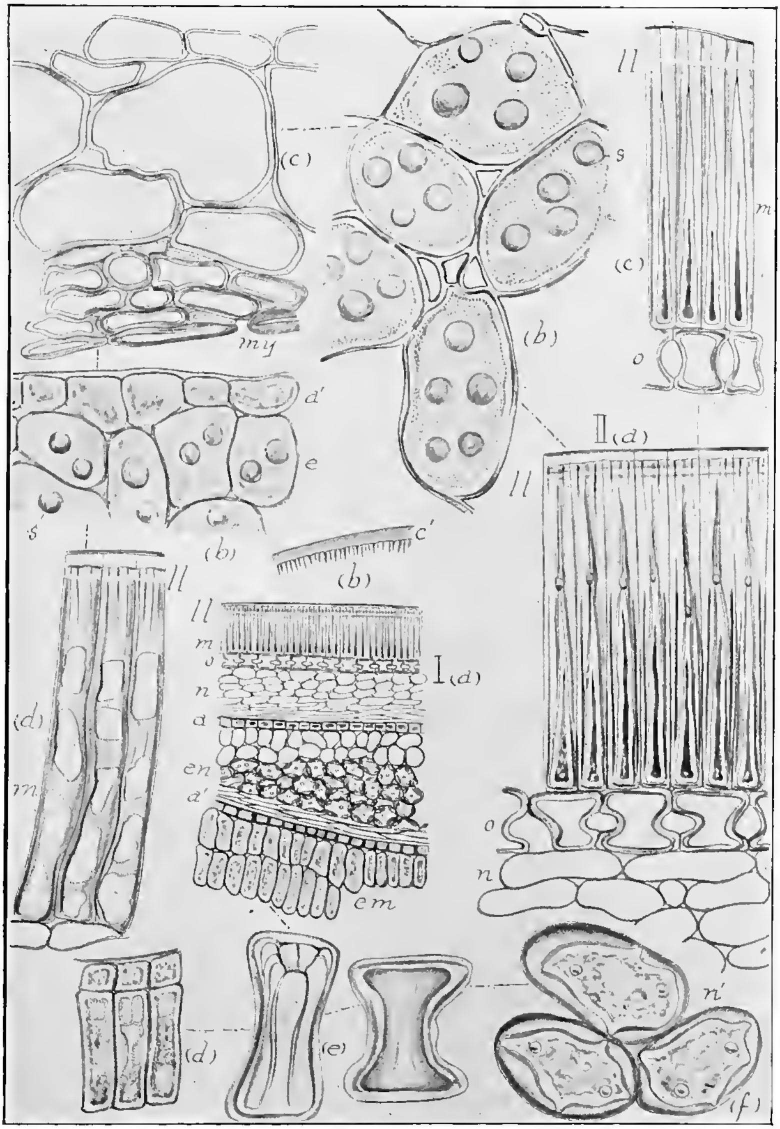

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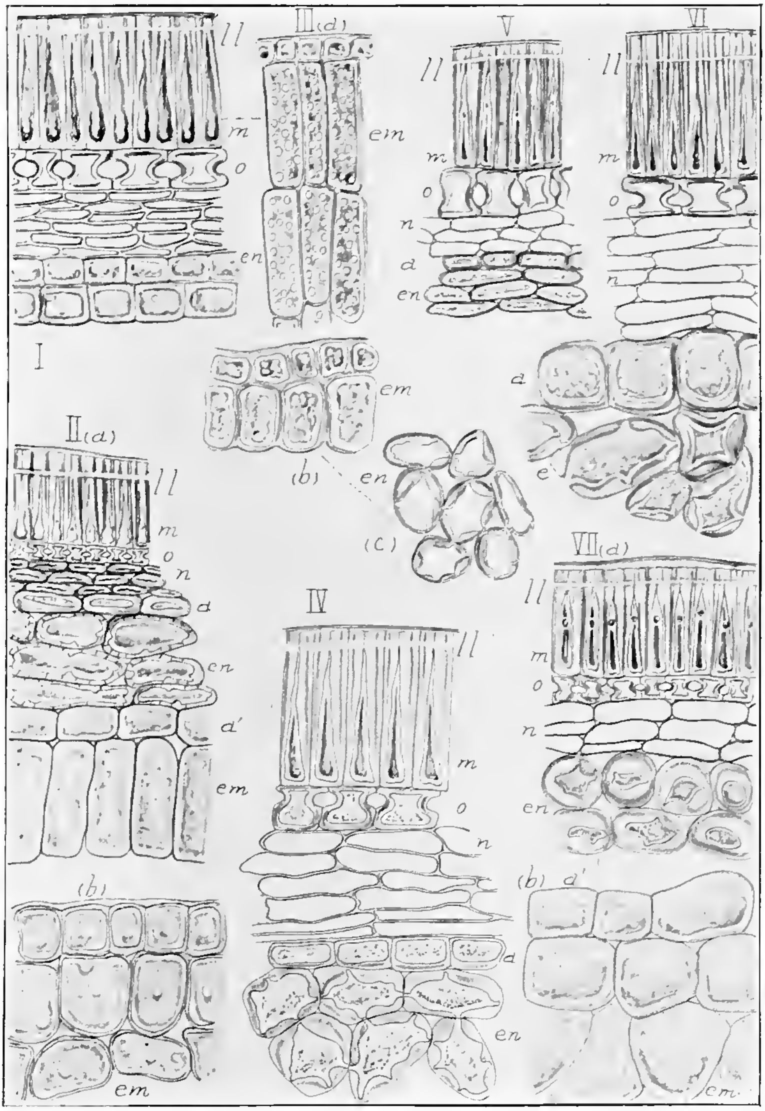

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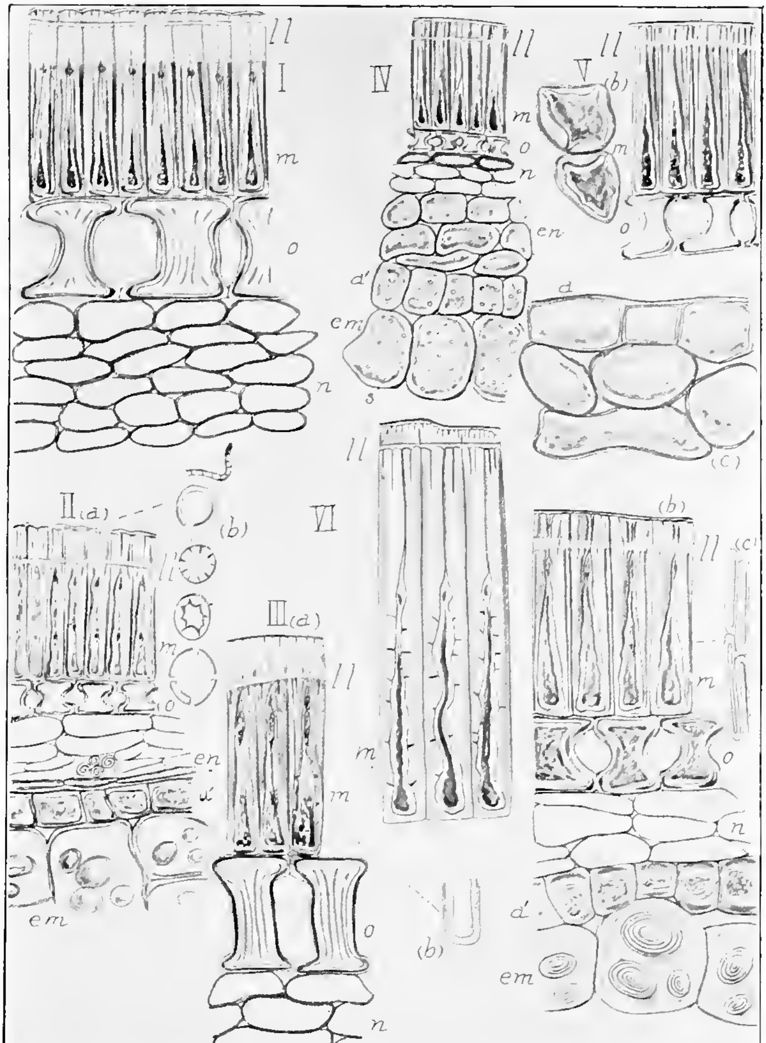

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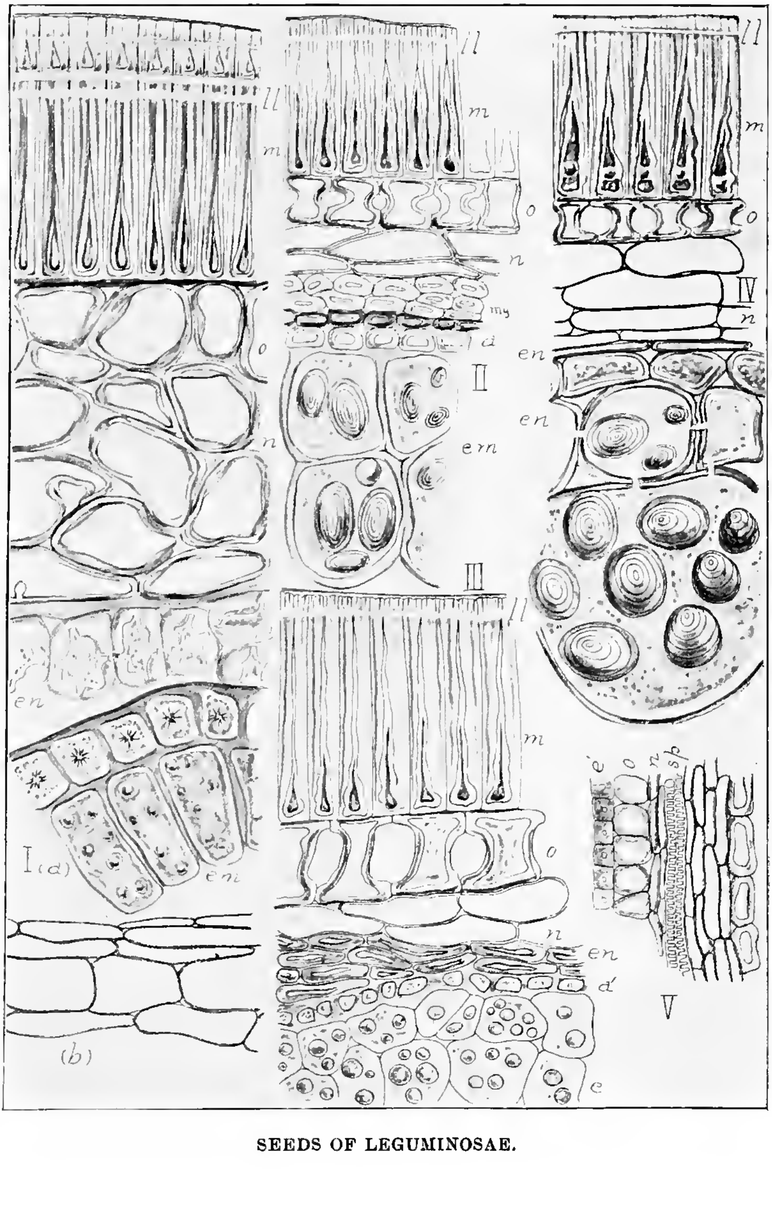

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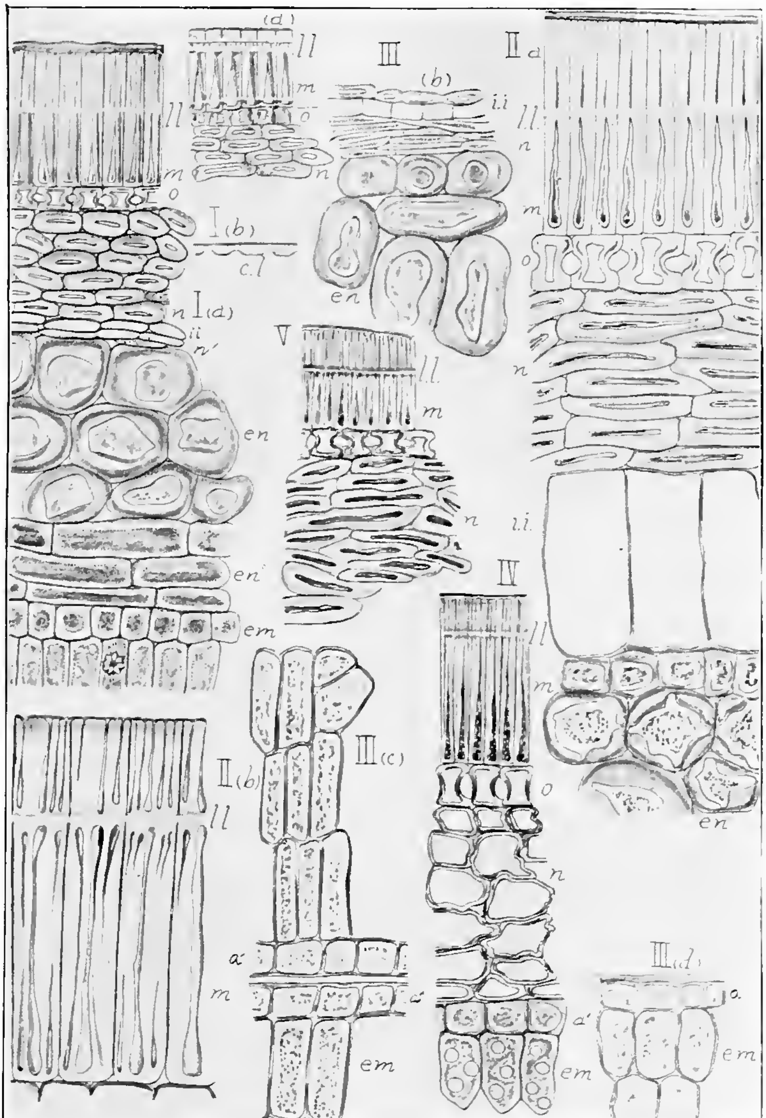

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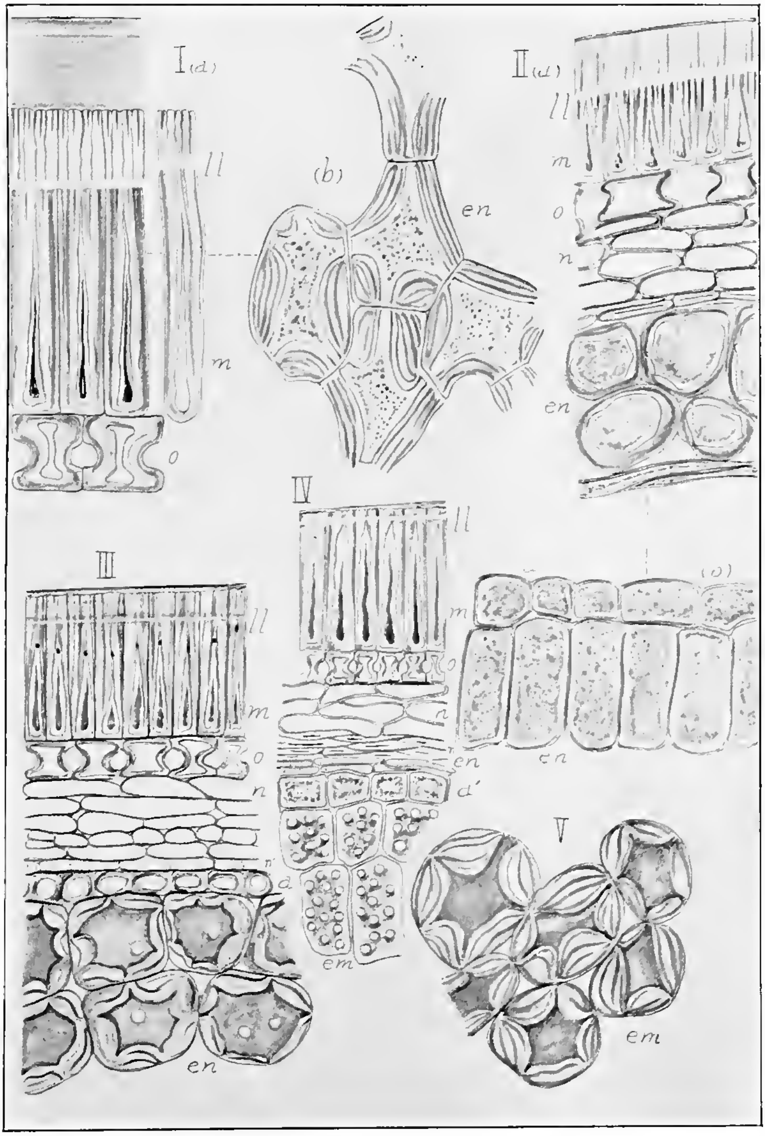

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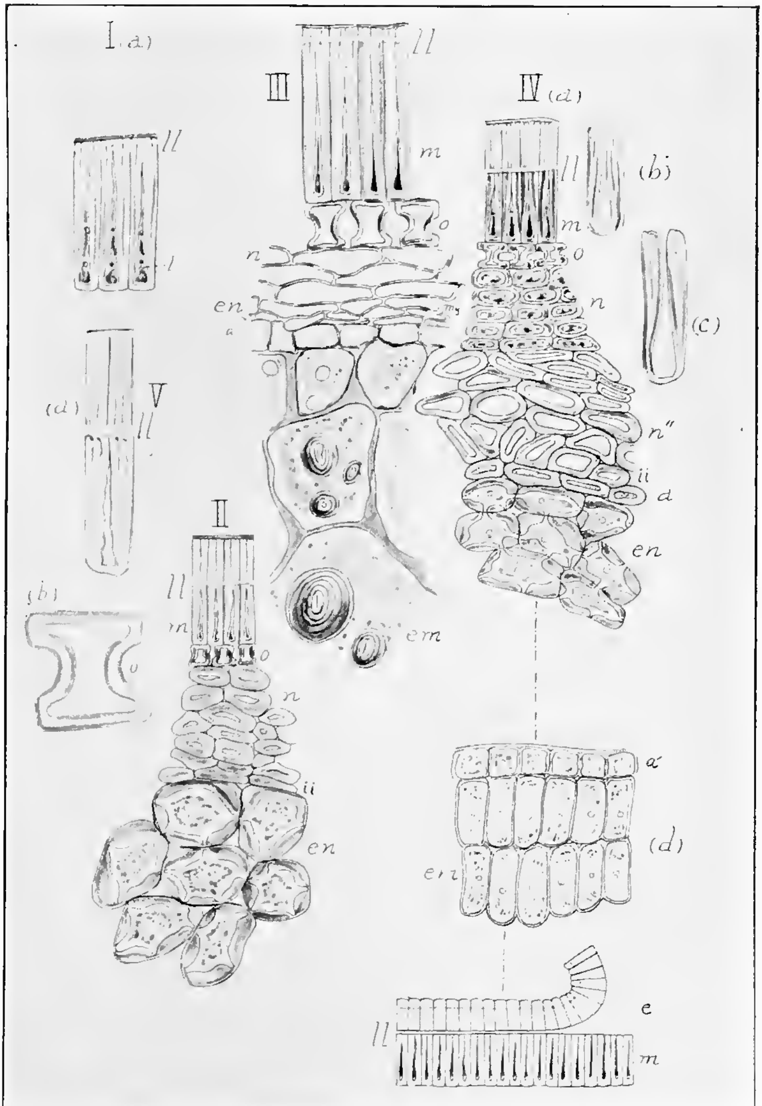

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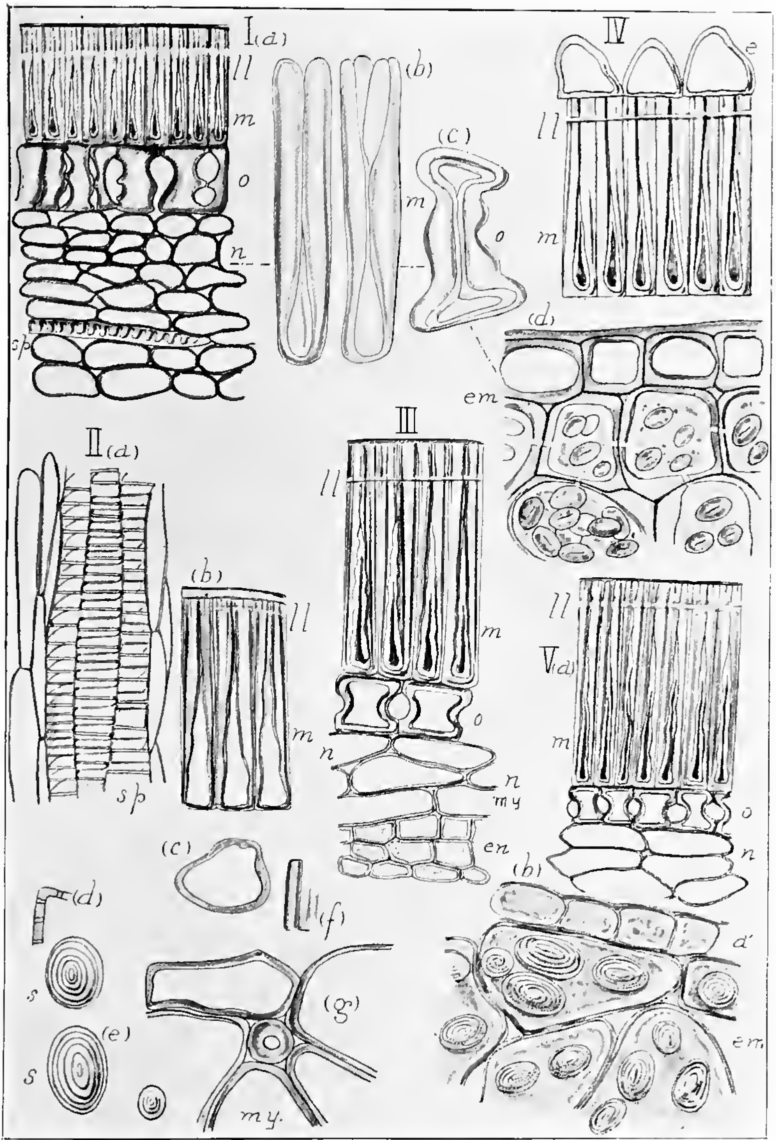

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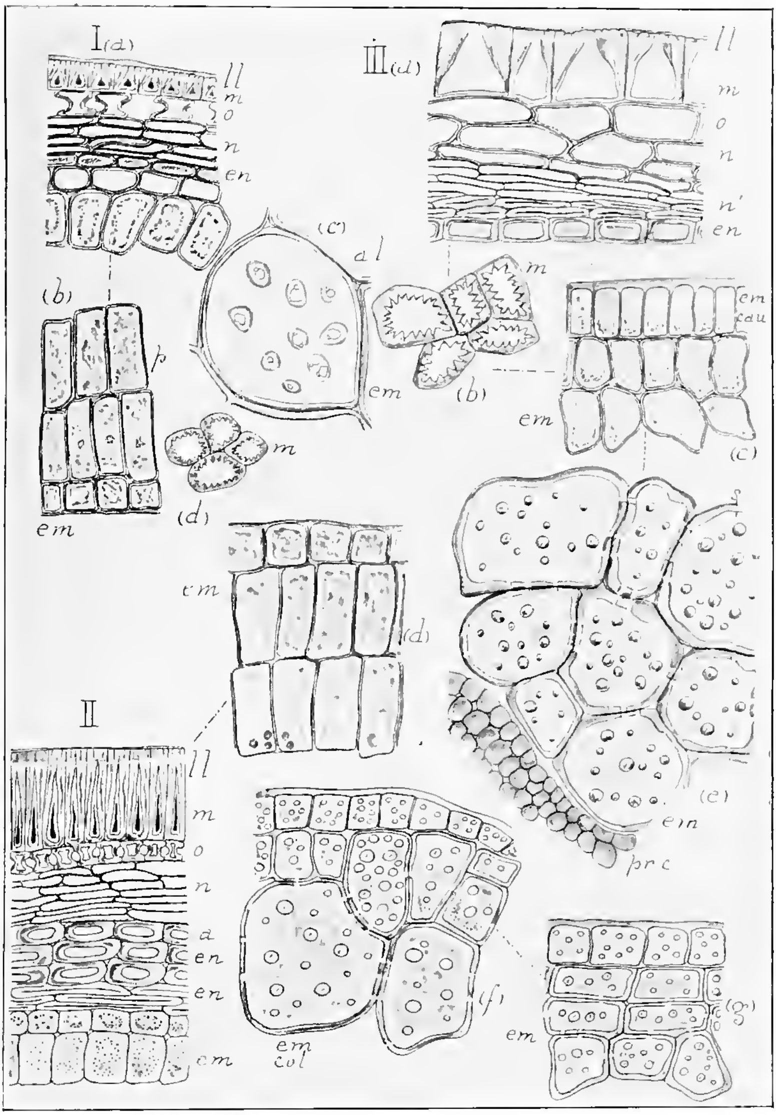

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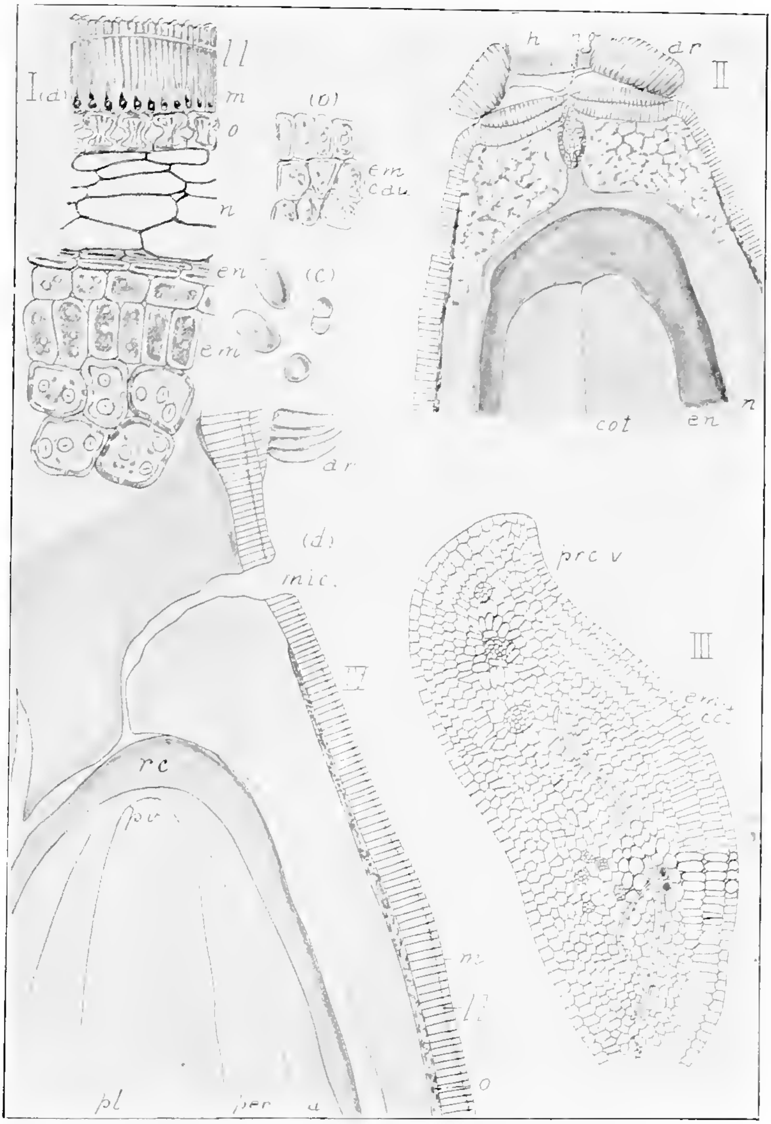

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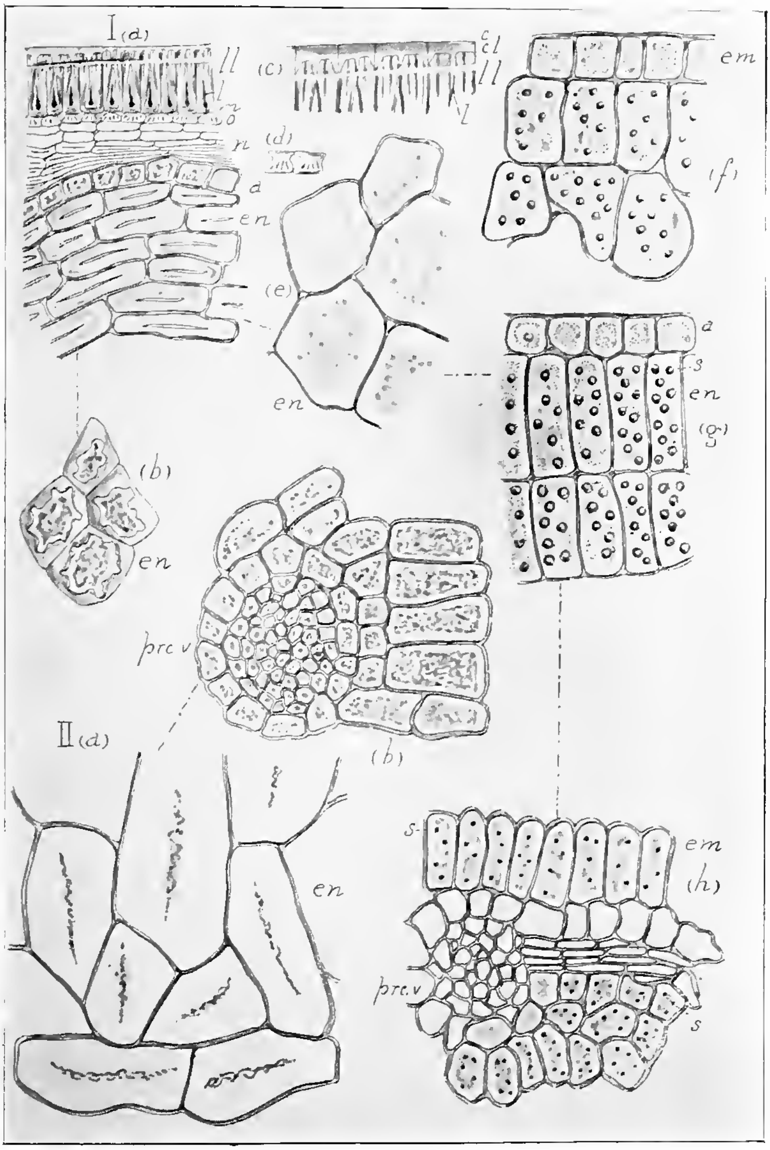

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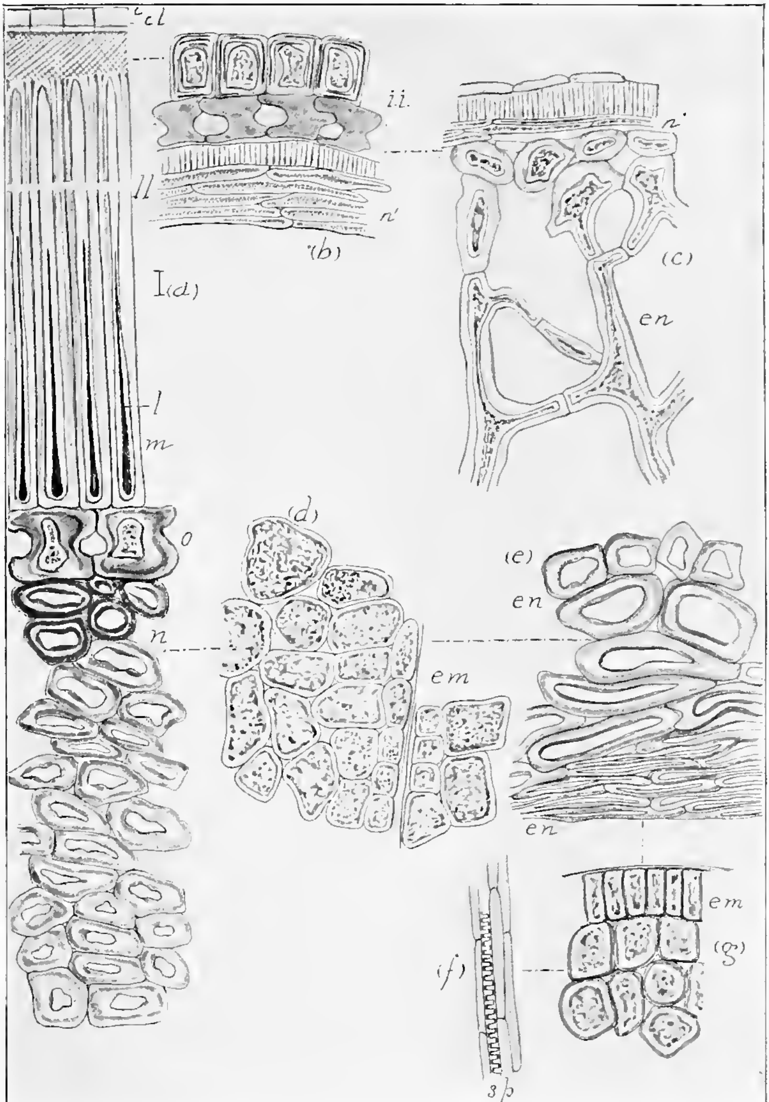

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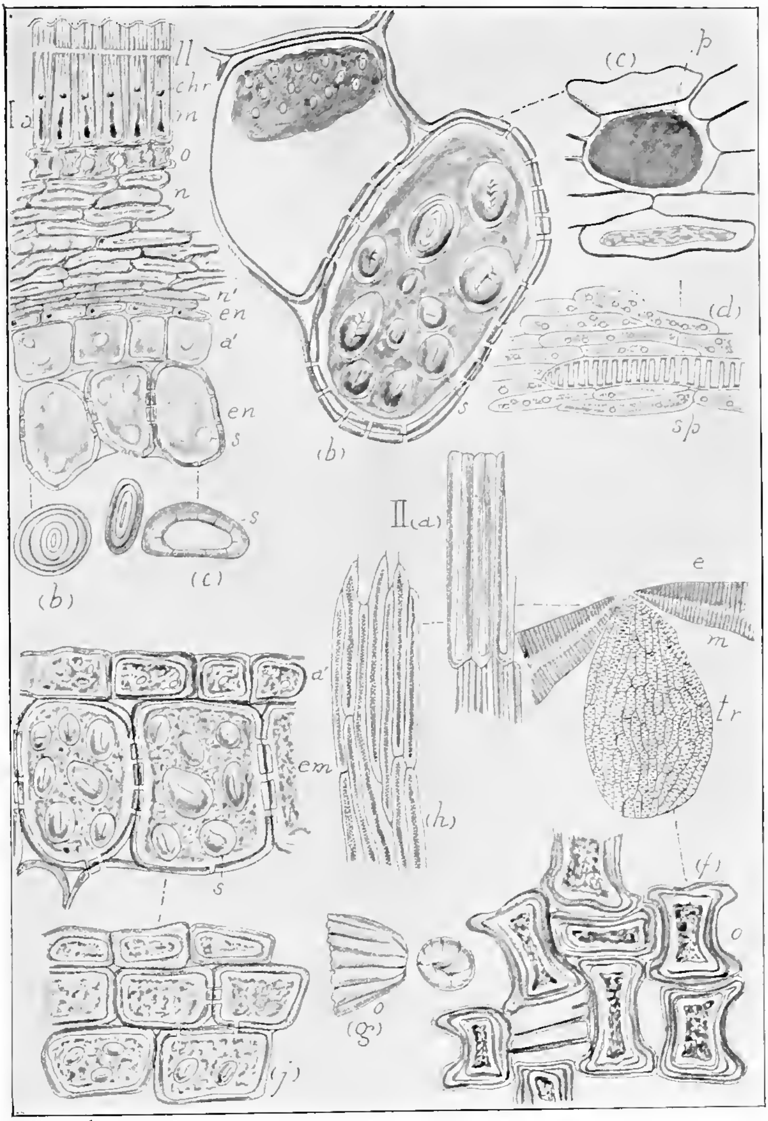

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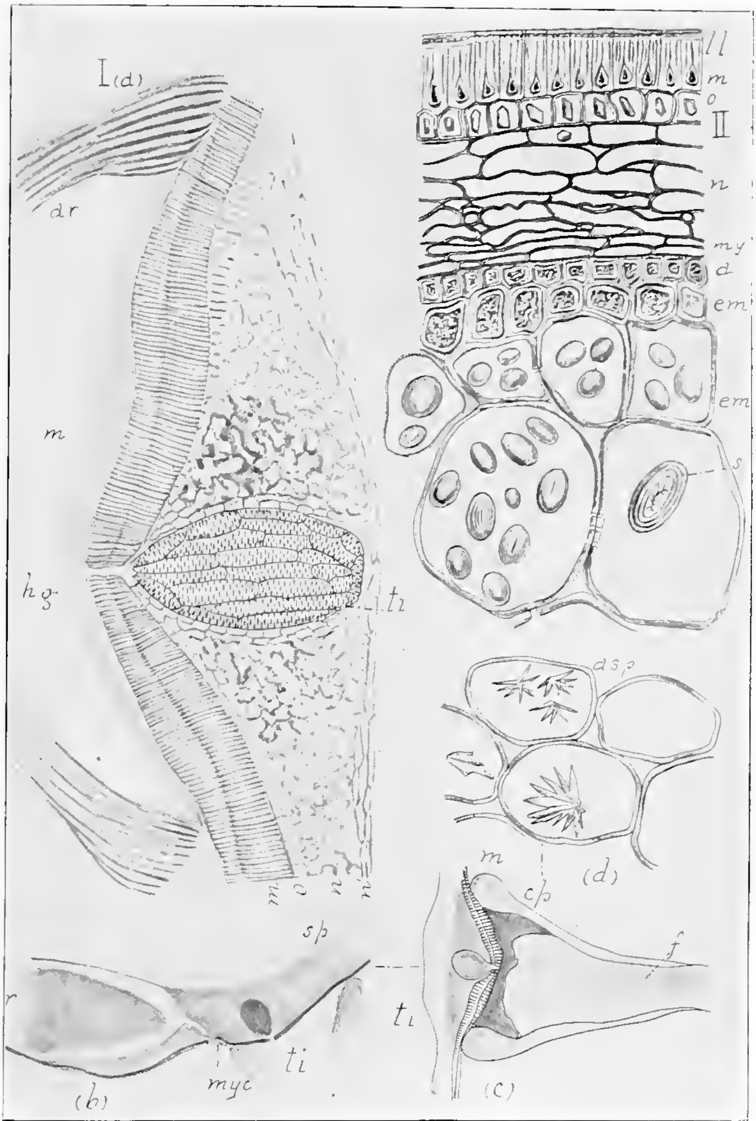

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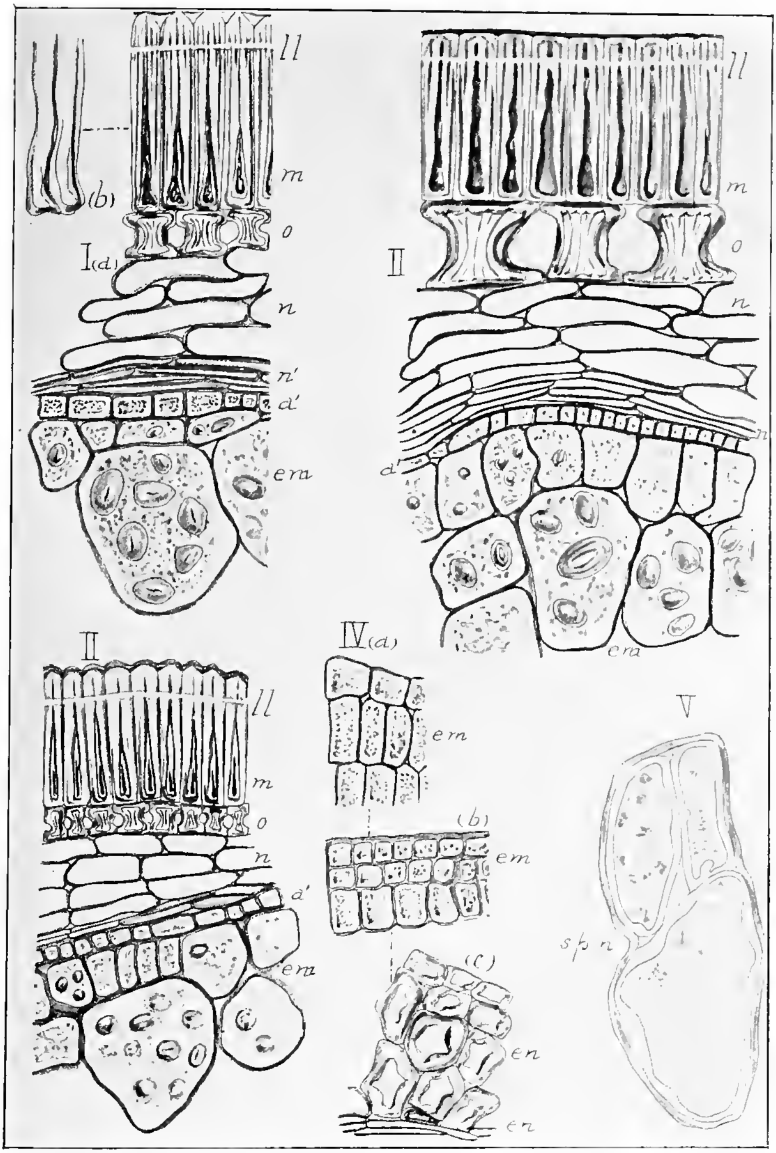

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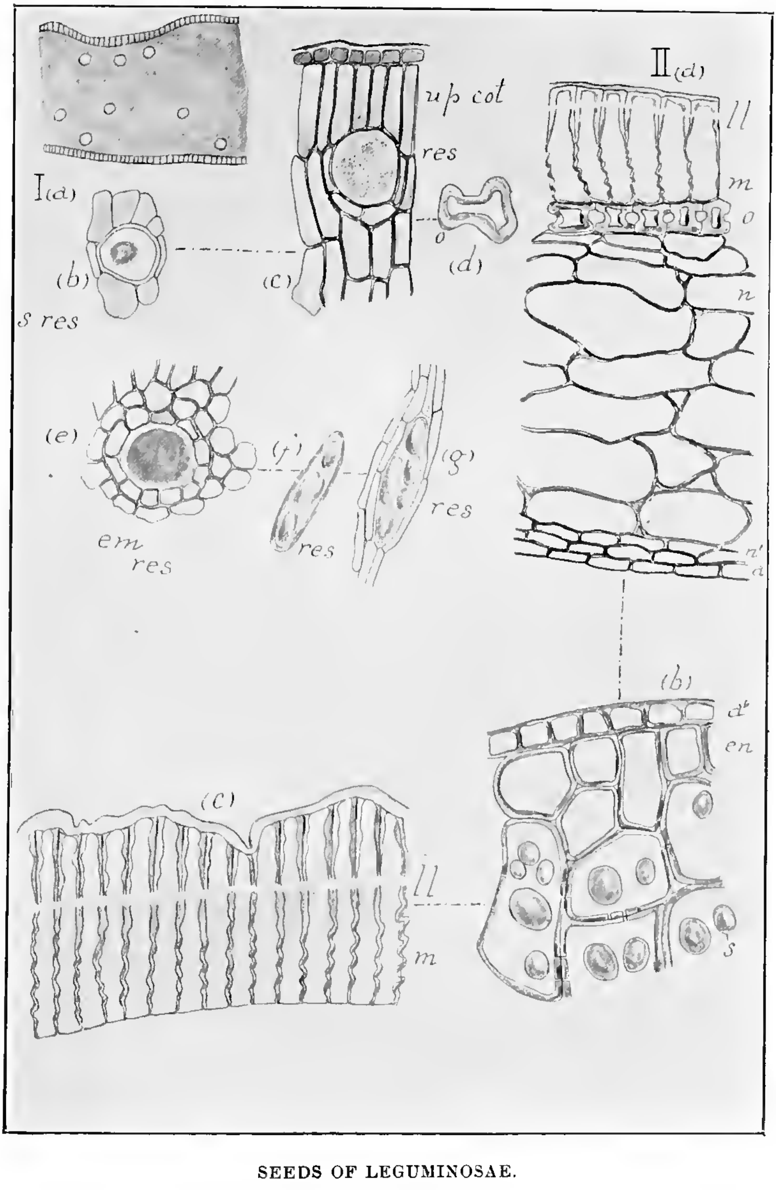

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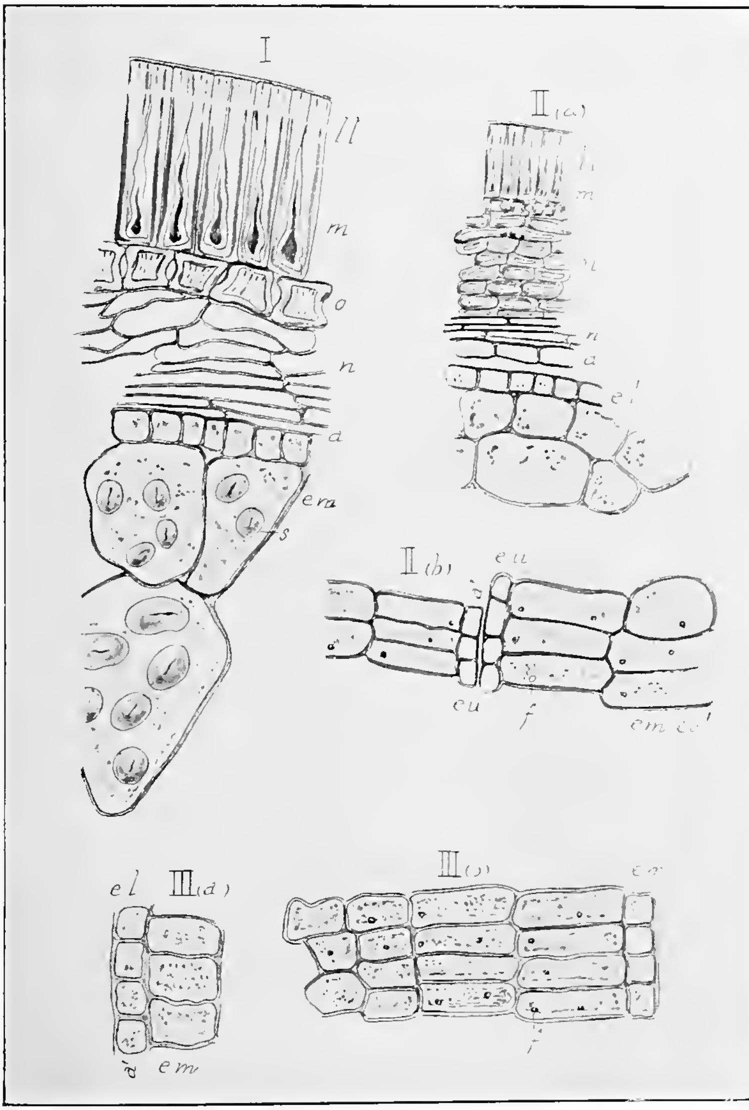

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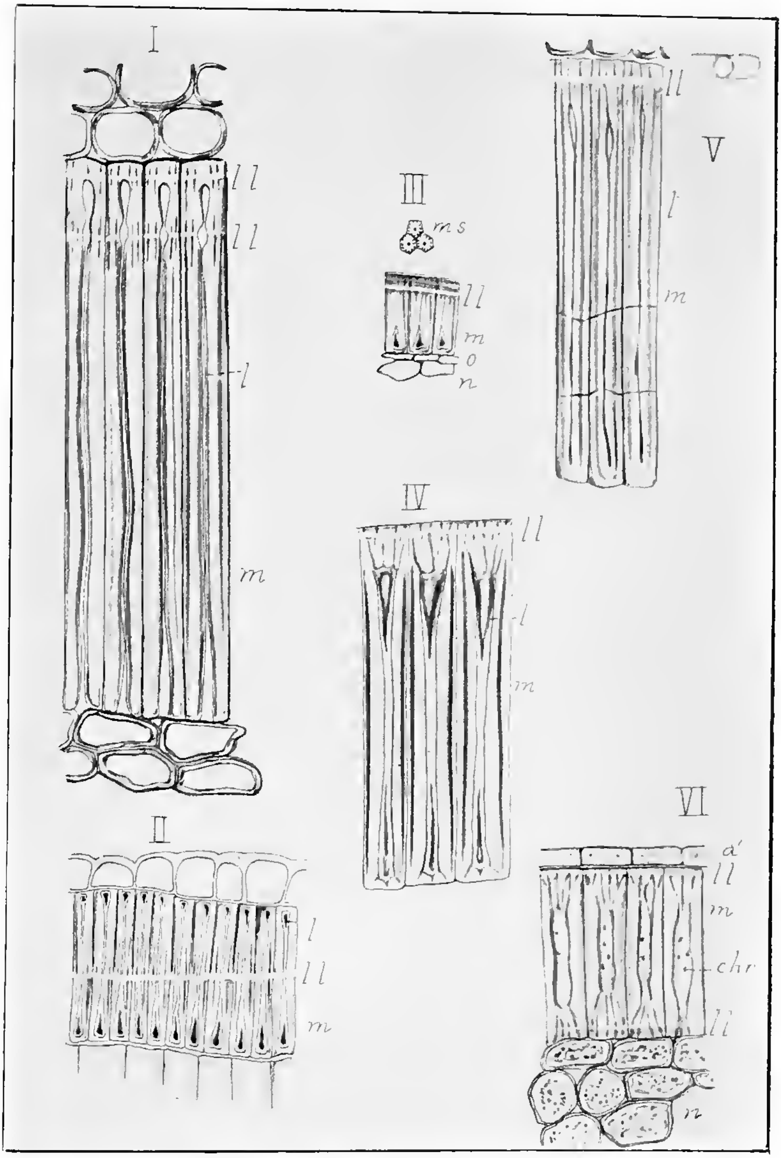

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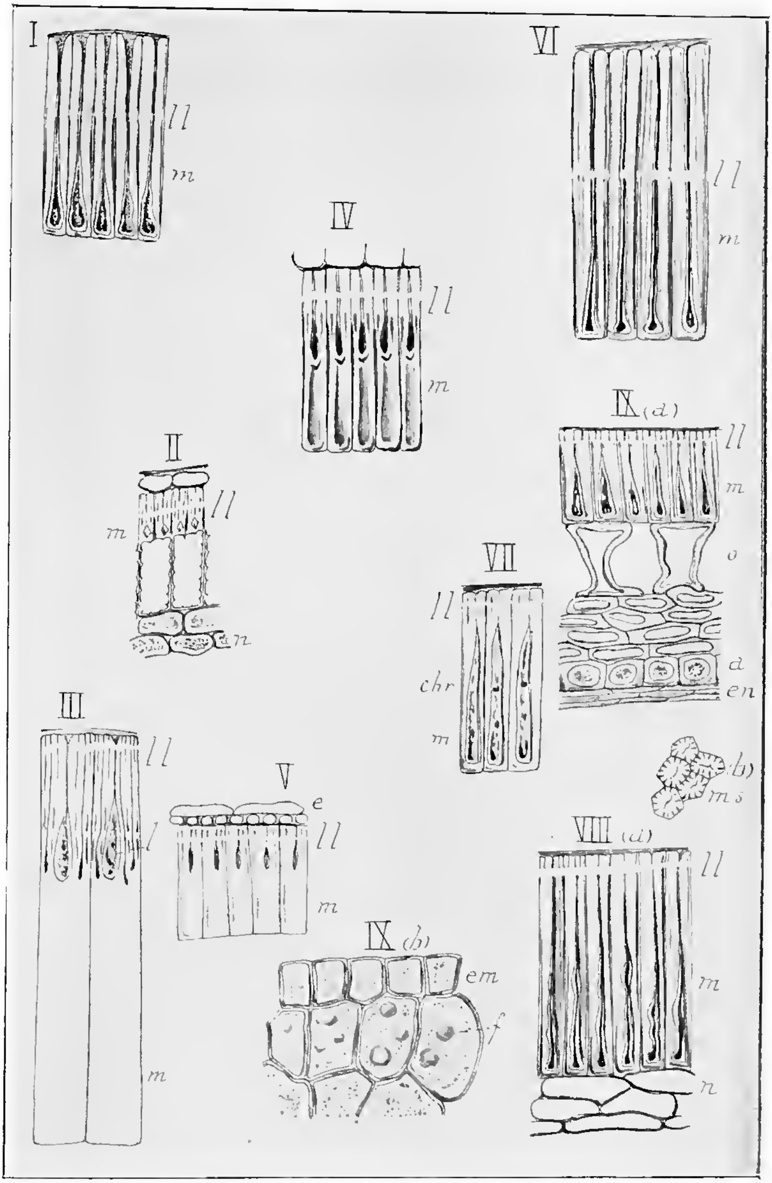

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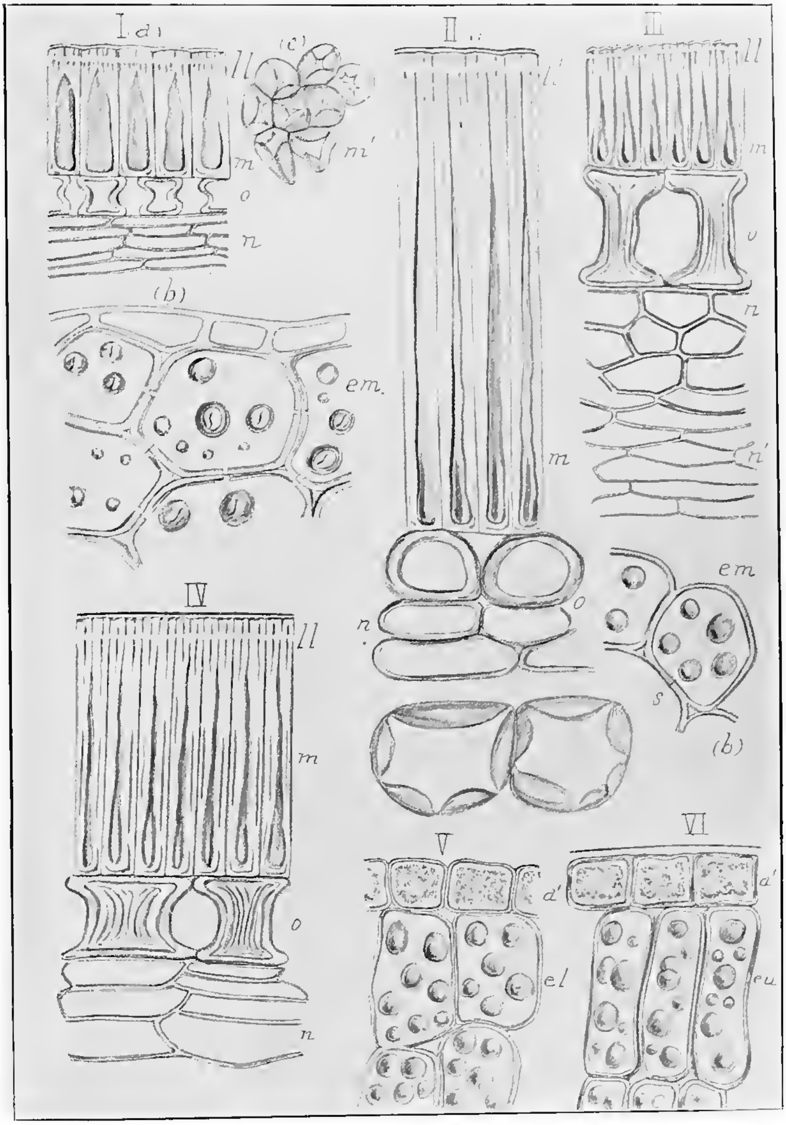

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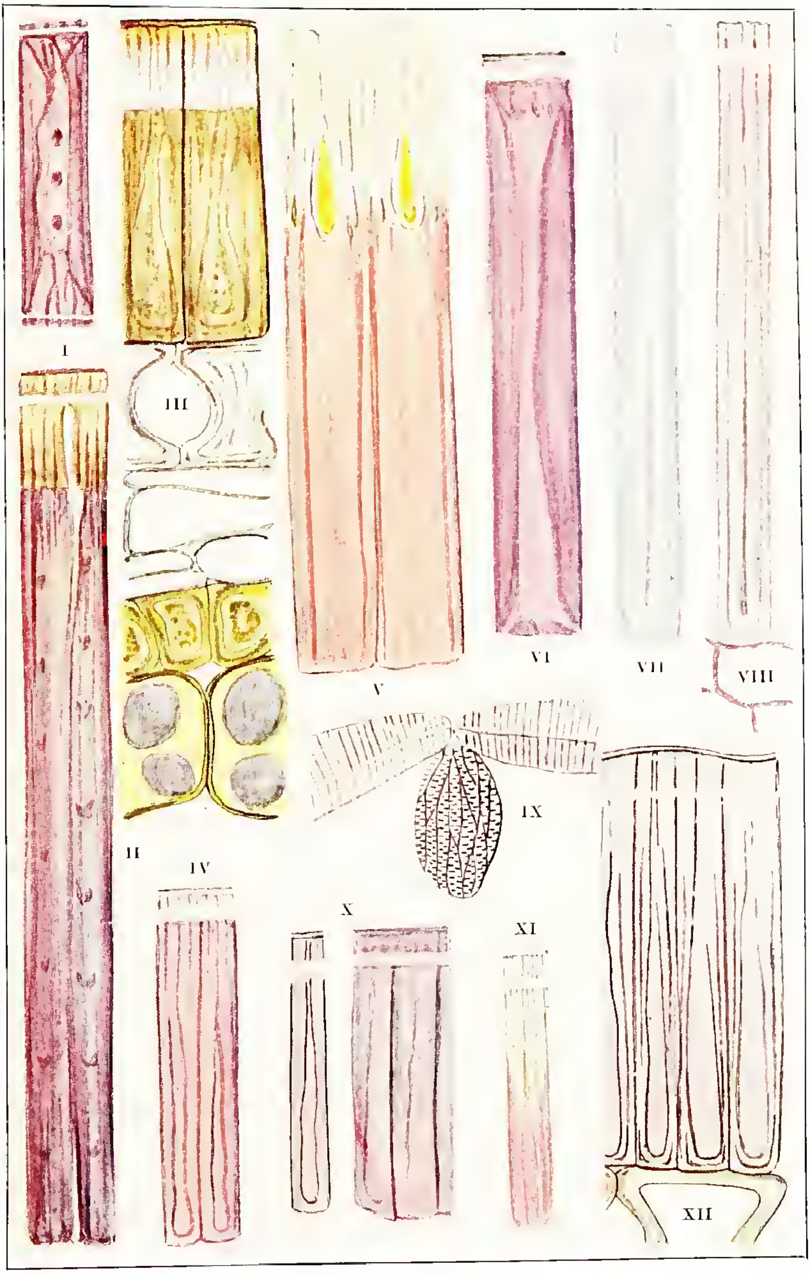

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